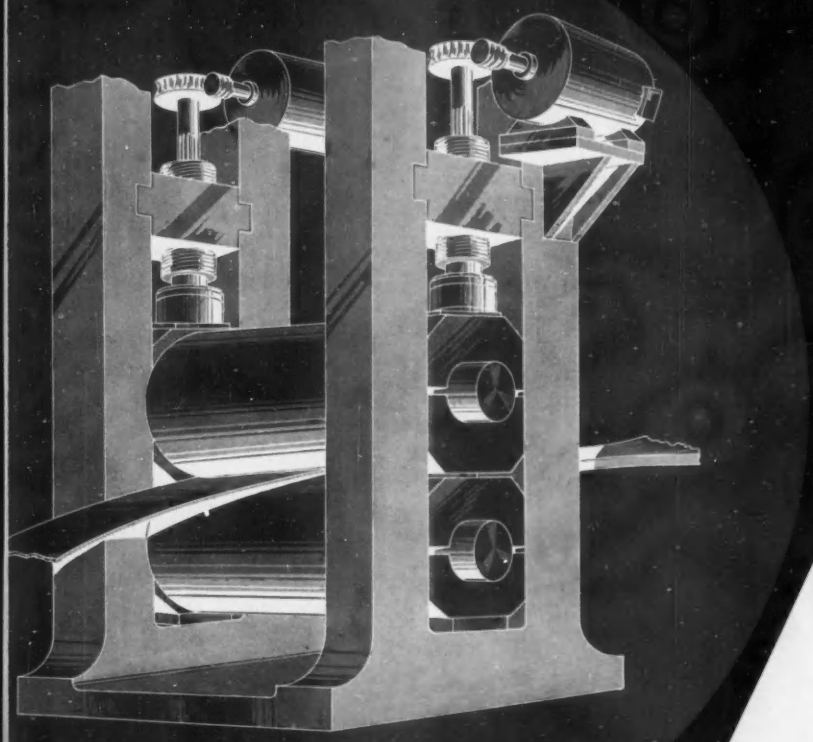
Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

A McGRAW-HILL PUBLICATION

PRICE 60 CENTS

OCTOBER 1957



A Report on

CONTROL IN BRITISH STEEL

The demands of computer and control projects and problems over a 20-year period have earned for Librascope an enviable record of experience which is demonstrated by versatility and reliability in the design, development and manufacture of successful equipment. New demands of missile projects are reflected in Librascope's *profiles of experience.* This knowledge can be focused on *your* computer-control problems with the assurance of success. Librascope invites your inqury in this field. A letterhead request will bring you the Librascope story.

Engineers interested in challenging new fields are invited to contact Glen Seltzer, Employment Manager.

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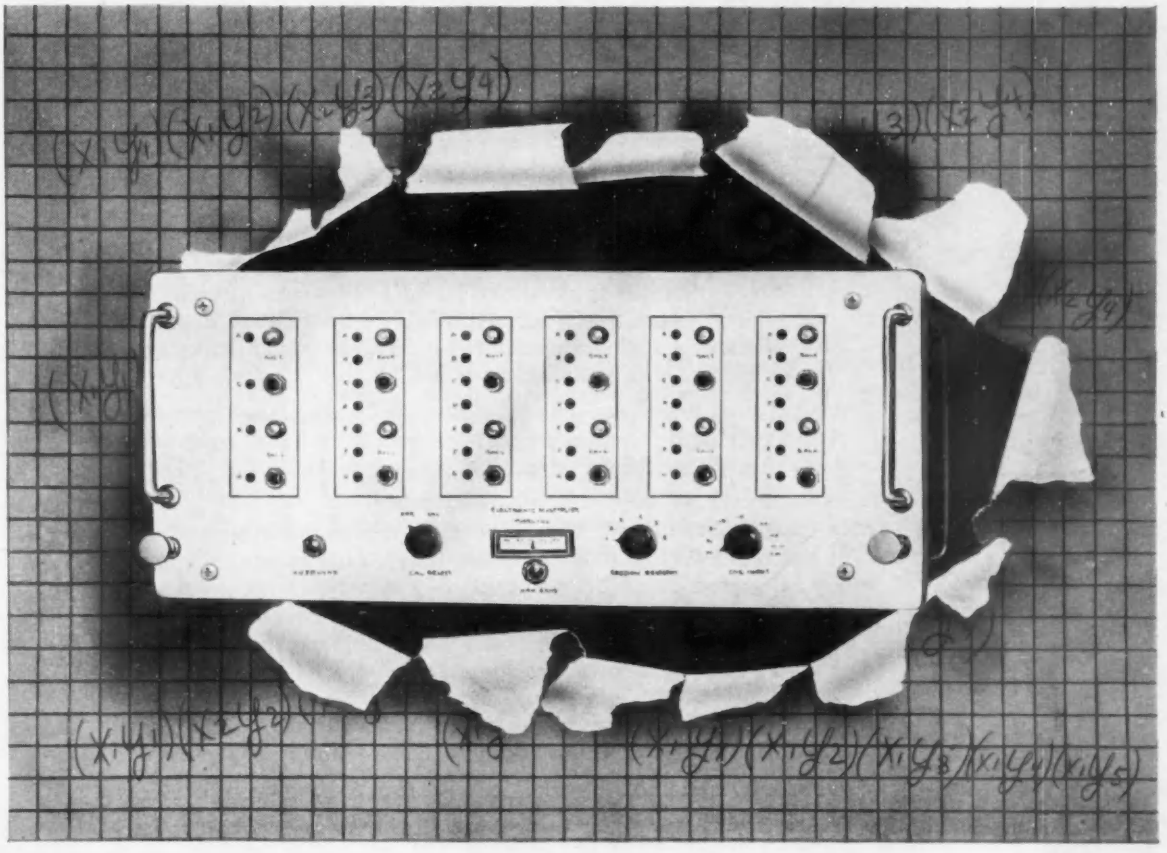


the first real advance in electronic multipliers

New GEDA M-160 permits custom-packaging of timer and output sections

How long have you wished for an electronic multiplier that would allow you to package timer and output sections at will—easily and accurately—to suit the needs of different computing problems? Well, wish no more, for here it is—the new GEDA M-160.

With the GEDA M-160, you can package any combination of *six* sections—timer or output—in a *single* module. Depending upon the requirements of the problem, you can obtain five products of one independent variable—four products involving two independent variables—or three products involving three independent variables. And, because output sections need not be matched to timer sections, you can interchange them at will with no sacrifice in accuracy.

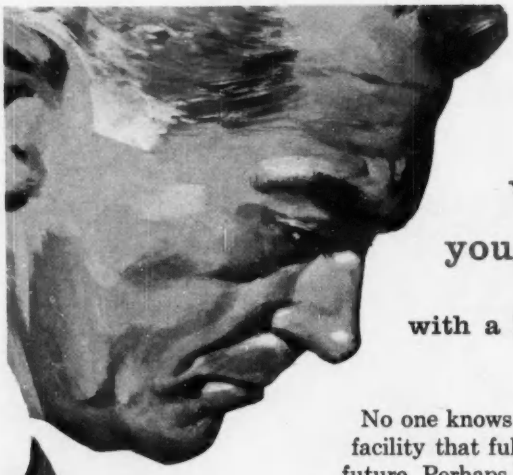
Conservatively speaking, accuracy of the GEDA M-160 is 0.02% of full scale—phase shift at 100 cycles is within 0.5 degrees—and noise output is substantially less than that of conventional electronic multipliers.

The new GEDA M-160 Custom-Packaged Electronic Multiplier is one more of the advanced-design and engineering features which make the GEDA A-14 Series the most accurate and flexible analog computers ever available. Get the complete GEDA A-14 story today. Write: Goodyear Aircraft Corporation, Dept. 913GJ, Akron 15, Ohio.

GEDA
ANALOG COMPUTERS

GOODYEAR AIRCRAFT

GEDA—T. M. Goodyear Aircraft Corporation, Akron 15, Ohio



Why crystal gaze...
you can start closing loops now

with a Beckman / 112 Data Processing System

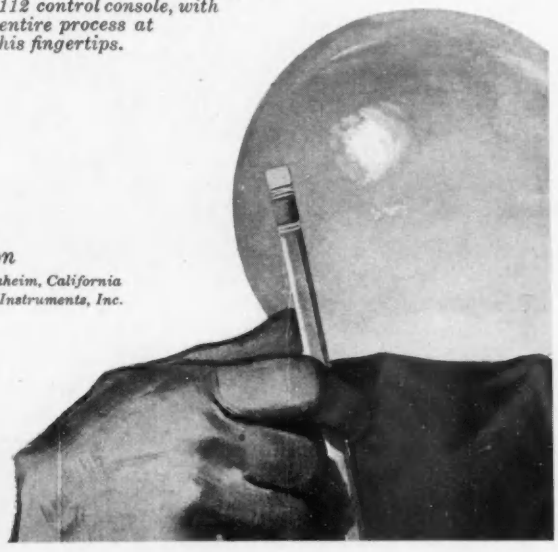
No one knows better than the operator of an on-stream process facility that fully automatic, closed-loop controllers are a part of his future. Perhaps he is already using data processors, or even closed-loop controllers of sorts—probably decentralized, multiple-instrument installations of analog equipment. No doubt he would like something better. He has been promised a whole lot more.

He has been promised accurate, reliable, fully integrated systems—closed-loop, digital controllers that will turn operational nightmares of today into the production dreams of tomorrow. And no doubt he will get them, but the question is *when?* Can he afford to wait?

He doesn't have to wait. He can swap his crystal-ball system of tomorrow for a mirror reflection of his processes today. An accurate, reliable, fully integrated data-processing system—compatible with automatic controllers—is already a "hardware" reality. The Beckman 112 System is at work in the process industries now. Combining the best features of analog and digital methods, the 112 is on the job around-the-clock—monitoring stream variables, giving off-limit warnings, performing the mathematical computations for continuous control, and producing digital readout in readily usable form.

For information on how Beckman Systems Division can provide you with a field-tested system to meet your process needs now, write for Data File D-12-46.

Operator sits at streamlined 112 control console, with entire process at his fingertips.



Beckman®

Systems Division

325 N. Muller Ave., Anaheim, California
a division of Beckman Instruments, Inc.

Control ENGINEERING

OCTOBER 1957
VOL. 4 NO. 10

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS
Published for engineers and technical management men who are responsible for the design, application and test of instrumentation and automatic control systems

Continued on next page ▶

Control ENGINEERING

General Electric's G. W. Heumann, who wrote the report on Russian industrial control (page 22) is well-acquainted with European control techniques. He received a master's degree in electrical engineering at Germany's Technical University of Dresden 27 years ago, and today he's an active spokesman for control in U. S. professional societies. One of the deepest impressions made on Heumann during his Russian tour was the apparently great progress by the Russian economy in the past few years, particularly its tremendous activity in new housing — a notorious Soviet weakspot.

Published monthly by McGraw-Hill Publishing Co., Inc., James H. McGraw (1860-1948), founder. PUBLICATION OFFICE, 99-129 North Broadway, Albany, N. Y. EXECUTIVE, EDITORIAL, and ADVERTISING OFFICES: McGraw-Hill Building, 330 West 42nd Street, New York 36, N. Y.

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Position and company connection must be indicated on subscription orders. Single copies 60c, except $2 for September issue. U.S. and Canada: one year $5, two years $8, three years $10. All other foreign, one year $15. Second-class mail privileges authorized at Albany, N. Y. Printed in U.S.A. Title registered in U.S. Patent Office.

SUBSCRIPTIONS: Send subscription correspondence to Subscription Manager, CONTROL ENGINEERING, 330 West 42nd Street, New York 36, N. Y. For change of address, give old as well as new address, and include postal zone number. If possible, enclose address label from magazine. Please allow one month for change.

Simpler, faster, more accurate setup of function generators

with the EASE push-button servo system*

BRIEF SPECIFICATIONS

Model 1171 Function Generator

OUTPUT—Voltage Y, within —100 to +100 V, varying in 20 straight-line segments which approximate the curve of the function, with a desired functional relationship to input voltage X.

ACCURACY — Error in setting breakpoint, 0.1% of full scale; error in setting output value, 0.05% of F.S.; diode rounding effect for 1:1 change in slope, 0.1% of F.S.

DRIFT — 0.03% of F.S. over any one-hour period; 0.07% per day.

Model 1172 Setup Unit

PURPOSE — Provides push-button setup with checking facilities. Contains servo amplifier, switching, precision input voltage, output reference divider, and metering.

ACCURACY — Nulling error ±.03% of full scale.

MOUNTING—Fits standard EASE* cabinet or any standard relay rack.

DIMENSIONS—Panel, 8¾" x 19"; depth 14¼" plus connectors.

(Typical values: full scale = 200 V)

Standard plug-in amplifiers simplify servicing

EASE* 1100 Series computers offer unmatched speed and accuracy with virtual elimination of operator error in setting up function generators. Consistent with the advanced "human engineering" concepts reflected in all design aspects of this series, precise and completely reliable control of setup is accomplished simply, without adjustment of knobs.

Up to ten Model 1171 variable base function generators are at the operator's fingertips through the Model 1172 push-button setup unit. It provides separate three-digit arrays of push buttons for setting X and Y values for each generator; a simple null checking method for verifying output over the entire range of inputs; a meter enabling the operator to trim the function, and a panel scope for visual monitoring of the function curve.

Model 1171 biased diode type generators approximate single-valued functions by means of line segments; locate breakpoints with three-place accuracy. Each generator incorporates two plug-in DC amplifiers of extremely high gain, high frequency response and superior stability.

The Series 1100 servo-setup function generator system uses Beckman/Berkeley's new no-drag clutches, which act independently of each other, disengage completely after setting, and have operational life exceeding that of the pots themselves. This advanced engineering achievement is instrumental in providing push-button control with accuracy of ±.03% nulling error full scale. For complete information on the Beckman/EASE* 1100 Series, which is upgrading design and performance standards in the analog computer field, write to Dept. L10.

Beckman

EASE COMPUTERS

Mfd. by Berkeley Division, Beckman Instruments, Inc. Richmond 3, California

153 *Trademark

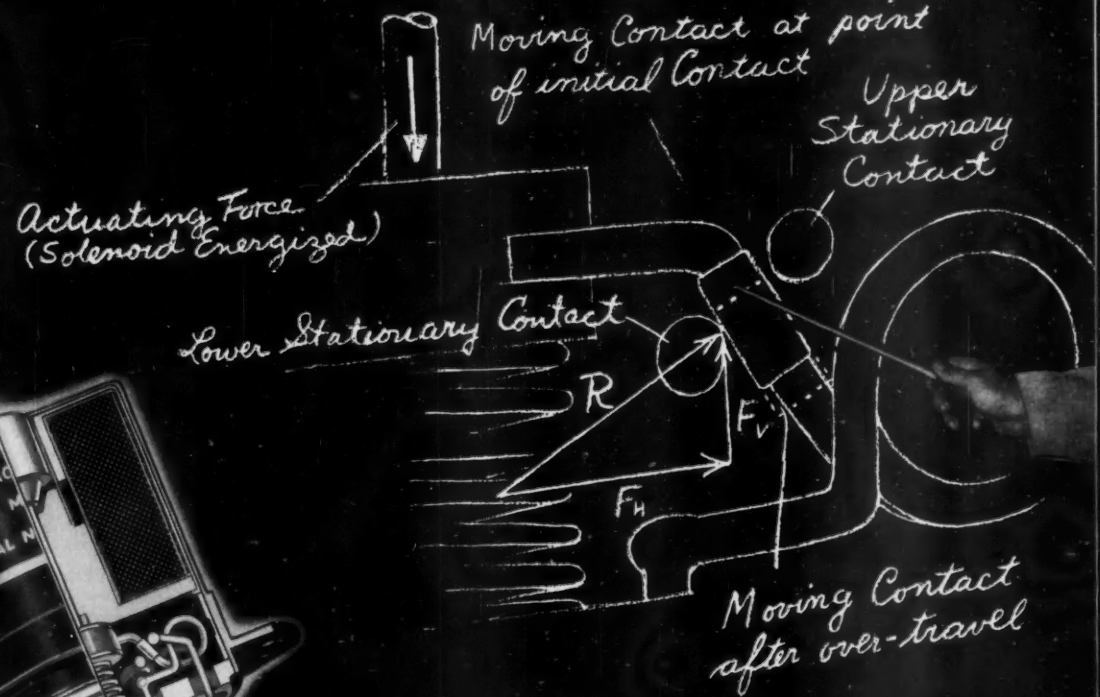
EASE Computer service is available on a rental basis. For full details, write George D. Bekey, Director, Beckman/Berkeley Computation Center, 307 Parkman Ave., Los Angeles 5, California

New, revolutionary Wedge Action

MARK II RELAY

Specifications:

Operating Vibration ... 5 to 2000 cps, 30 G's
Contact Rating ... Dry Circuit to 2 amps
Contact Arrangement ... 6 pole double throw
Ambient Temperature ... -65°C. to +200°C.
Contact Bounce ... None
Operating Shock ... 100 G's



Relay announced by ELECTRO TEC!

Now In Production!

NEW MARK II RELAY
AIDS ULTRA-RELIABILITY
under most extreme environmental and operating conditions.
(See specifications, left)

NOVEL WEDGE ACTION SWITCHING
provides positive contact in both energized and de-energized conditions.

Contact pressure constantly *increases* during over-travel.

Wedge Action now supersedes "Wiping Action".

- **Removes contaminants from contact surfaces.**
- **Reduces resistance to micro-level currents.**
- **Renders relay extremely resistant to shock and vibration.**

BRIEF DESCRIPTION: Six pole. Double-throw Miniature unit. Hermetically sealed. Meets and exceeds specifications MIL-R-5757C and MIL-R-25018.

Designers of critical modern electronic equipment, where ultra-reliability is vital, are invited to write—or *wire collect*—for further details on this entirely new and original high-performance relay concept.

Mark II Relay performance is based on an outstanding combination of extremely careful selection of precious metals and other component materials; novel—and exhaustively *proven*—structural design; unique precision production processes, exclusive to Electro Tec.

Mark II Relay Folder, or
Engineering Departmental Services, available on request.

ELECTRO TEC CORP.
South Hackensack, N. J.

Products of Precision Craftsmanship

PATENTS PENDING

SHOPTALK

From the Seafair to Disneyland

Starting at Boeing in Seattle during Seafair Week (which featured Northwest beauties and the Gold Cup races) Managing Editor By Ledgerwood pounded the West Coast beat for three weeks. He also visited Los Angeles and San Diego (via Disneyland) and ended up in the San Francisco area with a week at Wescon. There is a little discouragement on the coast because of recent military cutbacks and stretchouts, By reports, but the military control field is exploding higher than ever and a sizable interest in industrial control is becoming apparent as well. Prime areas of progress and interest are infrared techniques, inertial guidance, automatic test and checkout systems, and digital computer control, evidence of which will appear in the forthcoming issues of CONTROL ENGINEERING.

We're Not a Weekly, but—

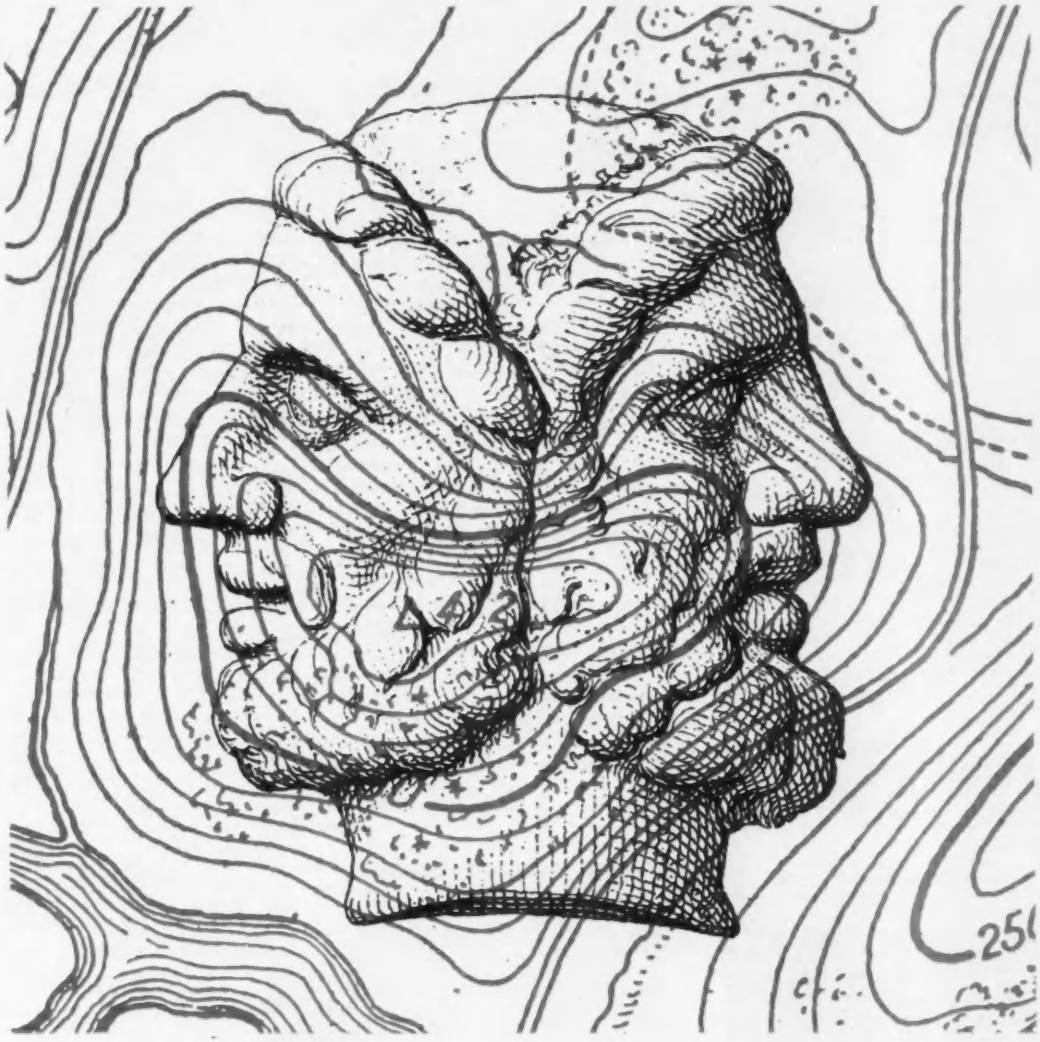
There's nothing that Associate Editor Lew Young likes better than a hot news story possibility right before closing. The Russian announcement of a successful ICBM gave him just this, and within a few hours he was using phone, Teletype, and telegraph to find out what missile scientists at White Sands, the Pentagon, Air Research & Development Command, and in England thought of this statement. Conclusion: They feel it is true and were not surprised, though the general public was. For the complete story, see page 30.

A Place in the Sun

No, this isn't about a moving picture, but about Editor-in-Chief Bill Vannah's keynote talk to the Systems Engineering Workshop at the recent ISA meeting in Cleveland. In his usual straightforward manner, Bill outlined the field of modern control systems engineering and even introduced a new particle—the "Regutron" (second cousin to a photon)—in discussing the systems engineering universe.

And They Call This Work

How would you like a three-day junket, including a flight from Washington to the Naval Air Station at Pensacola, Fla., a helicopter ride out to the aircraft carrier *Antietam* for the first public showing of the new automatic carrier landing system developed by Bell Aircraft, and a return flight to Washington? Assistant Editor Frank McPartland thought it was quite a lark, but in addition was mighty impressed by the accuracy of the system and by the faith that Lt. Cmdr. Don Walker, Navy test pilot, had in it. See *What's New*, page 34, for details.



Janus Comes Down To Earth

ROMAN MYTHOLOGY'S guard of the gates of Heaven was a concept which anticipated the many-sighted eye of today's color display tube. Color designation in display of microwave information increases our ability to differentiate moving from stationary objects, enemy from friendly aircraft, hazardous from safe terrain, meaningful signals from noise—to name only a few uses. We have for you a brochure on industrial and military applications of the Lawrence *single-gun* color display tube. Included in the brochure is an explanation of Post Deflection Focusing.

LITTON INDUSTRIES BEVERLY HILLS, CALIFORNIA
Plants and Laboratories in California, Maryland, Indiana, Utah and New York

DIGITAL COMPUTERS & CONTROLS RADAR & COUNTERMEASURES INERTIAL GUIDANCE SPACE SIMULATION RESEARCH
MICROWAVE POWER TUBES AUTOMATIC DATA PROCESSING SERVOMECHANISMS PRECISION COMPONENTS & TRANSFORMERS

FEEDBACK

What's in a word?

TO THE EDITOR:

We have attempted without success to find a generally accepted definition of the term "automation". Do you have a suitable definition or can you suggest where one might be obtained?

Clyde A. Norton
Remington-Rand Div.
Sperry Rand Corp.
South Norwalk, Conn.

We try not to use the word "automation," and so do most technical authors and speakers, because there is no agreed-upon definition; you get a different one from almost everybody you ask. In our concept, automation is a logical extension of a long-existing trend toward mechanization. There are a couple of agencies hard at work trying to establish a standardized definition, however. One of these is a study committee set up by the Engineers Joint Council and chairmanned by C. E. Davis of the ASME staff. Brown Instrument Div. of Minneapolis-Honeywell has published a report on a survey of what automation means to their customers; and Centralab, in its advertisement in technical magazines, has surveyed readers' opinions. Ed.

Information please—numerical control

TO THE EDITOR—

Is there available a text book that treats, from the elementary to the advance commercial development, the functions of magnetic tape as applied for linear positioning control mechanisms and, more particularly, as applied to control of machine tools?

How is the signal fixed in or on the tape and how is it sensed or read?

What are your suggestions for sources of information?

W. F. Newhouse
Saranac Machine Co.
Benton Harbor, Mich.

No book of the type you're looking for is available. However, the following group of articles published in CONTROL ENGINEERING should furnish you the information you need on principles and commercially available components.

1. "Digitalize Shaft-Position by Induction," November 1954, p. 54.

2. "Measure Motion to 0.0001 in. Without Friction or Wear," April 1955, p. 50.

3. "Automatic Machining–A View and a Preview, Pt. 1," September 1955, p. 112, Pt. 2, November 1955, p. 77.

4. "Numerical, Punched Tape, Machine Tool Control System," September 1955, p. 132.

5. "Tracing an Electronic Contouring System–From Idea to Application," April 1956, p. 65.

6 "Inchworm Holds Tools to Micro-inch Accuracy," September 1956, p. 40.

7. "Machining From Recorded Information," September 1956, p. 110.

8. "Automatic Programming of Numerically-Controlled Machine Tools," October 1956, p. 65.

9. "Digital Machine-Tool Control Simplified," December 1956, p. 103.

10. "The Power-Stepping Motor–A New Digital Actuator," January 1957, p. 74.

11. "Punched Tape to Shaft Position–Mechanically," January 1957, p. 111.

12. "Can you Take Advantage of the Cyclic Binary Code?", March 1957, p. 87.

13. "Applied Digital No. 11: Analog-to-Digital Converters," April 1957, p. 107.

14. "Interpolating Between Points for Continuous Machine Control," June 1957, p. 114.

And watch for the forthcoming November and December issues. They will feature a review and analysis, by Associate Editor John Cooney, of all commercially available numerically controlled point-to-point positioning systems. Ed.

Information please—data processing

TO THE EDITOR—

We are anxious to obtain two copies of the booklet, "Integrated Data Processing–A Factual Analysis," mentioned in CONTROL ENGINEERING, December 1956, page 161, reference 109.

Elliott Brothers
Century Works
London, England

To obtain copies of the booklet, write to Ditto, Inc., 6800 North McCormick Rd, Chicago 45, Ill. Ed.

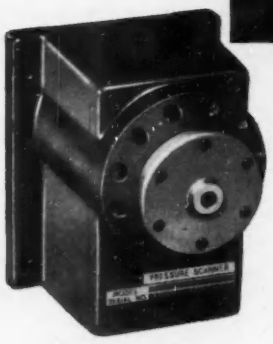
Information please—refinery simulation

TO THE EDITOR—

Please refer to page 173, CONTROL ENGINEERING, Vol. 4, No. 8, item "Refinery Simulation–From 'Use of

Multiple Pressures with **ONE TRANSDUCER**

the New DATEX PRESSURE SCANNER*



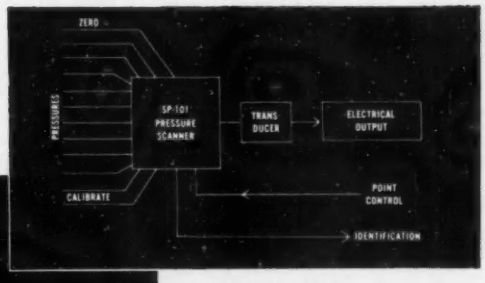
MODEL SP-101
PRICE $395.00

Designed to pneumatically switch a number of pressure sources into a single output port, the SP-101 Pressure Scanner introduces entirely new concepts into the field of pressure instrumentation. By providing an economical means of measuring a multitude of pressures, this device will accelerate the growth of automatic pressure recording in fields where it was heretofore economically unfeasible. Additionally, the pressure scanner not only reduces the number of transducers required for multiple pressure measurement but can be used to increase accuracy of measurement with presently available components. This is done by automatically introducing calibration and/or zero pressures during each recording cycle, permitting calculation of exact transducer response; and thus enabling greater measurement accuracy. Also, since the transducer is vented to atmosphere between pressure ports, hysteresis effects are minimized, contributing to greater measurement accuracy.

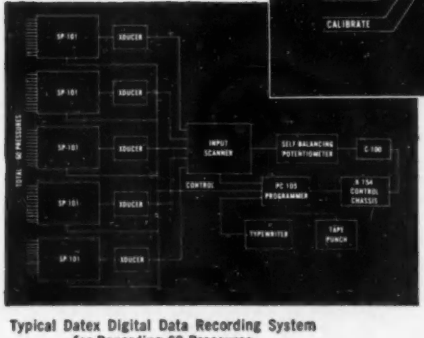
Basically, the SP-101 consists of a stator having 12 input ports, and a rotor that connects any one of the twelve input ports to an output port. The rotor is rotated to a desired position by a unidirectional high-torque motor, whose operation is controlled by means of a positive positioning arrangement. A relay circuit is incorporated in the unit to provide dynamic braking in order to stop the motor in a position where the rotor and stator ports are in coincidence.

The SP-101 Pressure Scanner can be used in applications that require the measurement of 12 pressures, all within the same transducer range. The unit can be externally programmed to switch pressures in any sequence desired, or it can be operated by means of a manual switch to select pressures to be measured.

TYPICAL SYSTEM USING ONE TRANSDUCER



*MANUFACTURED UNDER LICENSE FROM UNITED AIRCRAFT CORP.



Typical Datex Digital Data Recording System for Recording 60 Pressures

SPECIFICATIONS

FLUIDS:
Air and non-corrosive dry gases

PRESSURES:
From 0.1 psia to 350 psig

POWER:
50 watts, 115V a-c, 60 cycle

CONNECTIONS:
Input and Output–⅛" NPT

POSITIONS: 12

Designed for bulkhead mounting.

For additional detailed information, write for Bulletin SP-101-1.

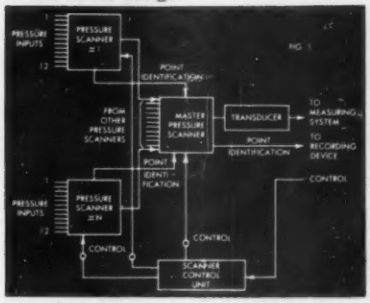
GIANNINI DATEX® DIVISION

1307 South Myrtle Avenue, Monrovia, California

G. M. GIANNINI & CO., INC. 918 EAST GREEN STREET • PASADENA, CALIFORNIA

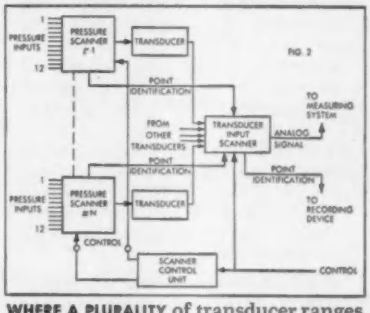
APPLICATION NOTES:

BY USING ONE pressure scanner to interrogate twelve other pressure scanners, as many as 144 pressures can be measured with only one transducer. A block diagram of a typical system is shown in Fig. 1. The 144 pressure inputs are connected to twelve pressure scanners. One output for each of these scanners will be connected to the input ports of an additional pressure scanner. The output of the latter scanner will thus sequentially scan the inputs of the 144 pressure variables. The aforementioned system is generally applicable where all pressures fall within the same range.



IN NUMEROUS APPLICATIONS, such as in engine test and wind tunnel operation, pressures vary over a wide range during the course of a recording cycle. With conventional multi-pressure recording systems, considerable measurement errors often result when the pressure drops to a small percentage of full scale.

IN ORDER TO ACHIEVE greater accuracy of measurement, the overall range is broken up into a plurality of smaller ranges. The SP-101 in combination with other Datex components can be used in an arrangement allowing the value of the pressure to be determined prior to measurement: permitting the appropriate pressure range to be selected so the optimum measurement accuracy can be provided.



WHERE A PLURALITY of transducer ranges are required, the input pressures are connected to the pressure scanner associated with the range which will offer greatest accuracy. This system is illustrated in Fig. 2. An increase in overall system speed is possible over that of the single transducer operation. As an example; assume a system containing ten pressure scanners that will be controlled in two groups of five each. While the transducers associated with the second group are being scanned, the first group is positioned to the next point. In this manner, the pressures of group number one are being stabilized while the transducers of group two are being recorded.

FEEDBACK

Computers in Refinery Simulation' by A. F. Pixley, IBM Petroleum Dept., a paper presented at the ISA Instrumentation and Control Symposium, Berkeley, Calif., May 14, 1957". From whom may we procure this paper?

G. I. Randall
Canadian Oil Cos., Ltd.
Corunna, Ontario

Write to Mr. Pixley at the IBM district office, 120 Montgomery St., San Francisco 4, Calif., for a copy of the paper. We have no word yet that proceedings of the symposium will be published. Ed.

Information please—telemetering

To the Editor—

Could you send us information as to where the proceedings of the 1956 Telemetering Conference are available and the price of this literature?

James G. Phillips
Eberline Instrument Div.
Reynolds Electrical & Eng'g Co.
Santa Fe, N. M.

The price of the proceedings is $3. Obtain your copy from Mr. Hugh Pruss, Federal Electronic Corp., 1136 Los Palmas Ave., Los Angeles 38, Calif. Ed.

Information please—testing on-the-fly

To the Editor—

We have read the article "Testing Metals On-the-Fly with Eddy Currents" (CtE, Vol. 4, No. 8), and would like to contact manufacturers of this type equipment. Our interest is weld inspection of aluminum and steel tubing.

Dean W. Roper
Gordon & Morgan Machine Co.
Lincoln, Neb.

Ditto

To the Editor—

Refer CtE, Aug, '57 issue, page 79, article on eddy currents. Would you send us the name of the instrument company which handles the eddy current detector.

S. J. Fitzgerald
Diesel Equipment Div.
GM Corp.
Grand Rapids, Mich.

Mr. Hochschild, the author of the article, reports these sources of eddy-current testing equipment:

1. **Metrol, Inc., PO Box 485, Berkeley 1, Calif. (his company)**
2. **Magnaflux Corp., 7300 W. Lawrence Ave., Chicago 31, Ill.**
3. **Magnetic Analysis Corp., 511 5th Ave., New York 17, N. Y.**
4. **J. W. Dice Co., Englewood, N. J.**
5. **Institut Dr. Förster, Reutlingen/Württ, W. Germany.**

He advises that the Institut Dr. Förster holds top world position in this type of testing. Ed.

Information please—IFAC

To the Editor—

I saw in the last issue of *Ingenieria Internacional-Industria* an article about the International Federation of Control Engineers, in which I am particularly interested, as my work is related to these lines. I would, therefore, like to have more information on this subject and presume that you are the one to furnish me with the necessary information so as to become a member of this association.

Ramon Salgado
H. Briones y Cia Ltda
Santiago, Chile

The item you read was a press release sent out to announce the formation of an international federation of automatic control. The organizing meeting will take place Sept. 10-12 in Paris. This country and Canada will be represented by North American Control Council delegates Rufus Oldenburger (Purdue Univ.), Harold Chestnut (GE), and John Lozier (Bell Labs). They will carry with them your request for individual participation in the technical and professional activities of the association.

CtE's European Editor will cover the organizing meeting and he'll also check the question of individual participation. The November issue of CtE will carry the story. Ed.

FORUM ON STANDARDS

One of us who attended the 21st Westinghouse Machine Tool Electrification Forum, April 24 and 25, talked with R. B. Colten of the General Motors Technical Center about the subject of his paper, "Standards for Industrial Electronic Equipment", presented there. Our discussion prompted us to abstract Colten's paper because it pointed out improvements in JIC standards which are

necessary for assuring minimum quality levels in manufactured industrial electronic control equipment. However, we withheld abstracting in favor of obtaining more up-to-date comments from the author. Here they are. Anyone care to add his two cents worth? A bright two cents worth will net you an engraving of The Great Emancipator. Ed.

To the Editor—

"Standards of Limited Scope" mentioned in my talk were prepared, some two or three years ago, by our group in the Process Development Section of the General Motors Technical Center and used. An Electronics Committee we have organized in the corporation has been in the process of preparing a preliminary set of standards for the past year. When completed, they will cover (quoted from the paper):

- ratings and specifications
- components
- physical construction
- wiring, soldering, and other connections
- instructions and diagrams, including symbols, nomenclature, and parts lists
- ventilation
- operating characteristics, including frequency and ease of calibration and adjustment.

We have no battle with "JIC Electrical Standards for Industrial Equipment" per se. These standards are a noble attempt to achieve a standard of quality previously unobtainable in electrical controls. Obviously, everyone cannot be expected to be in agreement with every detail in the specifications. However, specific deviation can always be agreed upon between purchaser and vendor. The JIC Standards were not originally designed to cover electronic equipment, and only in the last revision have they acquired any appreciable reference to electronic equipment.

These sections of the JIC Electrical Standards for Industrial Equipment adopted March 20-22 specifically refer to electronic equipment: E11.1.3 B (diagrams), E11.1.8A (symbols), E14.2.2 (voltages other than 115v), E15.1.5 (precision devices), E16.2.10 (ventilation of enclosures and compartments), E17.2.2 C (intermediate control panels), E20.2.2 (insulation), E20.2.5 (wiring), E20.2.2 (insulation and voltage ratings of internal wiring), E20.5b (minimum size of conductors).

FEEDBACK

E21.1.8 (wiring practices), E25.1.2 (testing), Appendix A (section on graphical symbols for electronic tubes), and about half of the device designations.

The following could be construed to apply to electronic equipment: E10.2,3,5,6,7,9; E11.1.1 A; E11.1.4, 5,6,7,8; E11.2.1,2,3; E11.3; E12.1,2; E12.5,6,8.1,8.3; E12.9; E12.10; E13.1, 2,4.1,4.2; Table II—Motor Overcurrent Protective Device Ratings, item on high-reactance squirrel-cage motors; E13.5.4; E14.2.1,3,5; E14.3.1; E14.4; E15.1.1,3,4,6,8; E15.2,5; E16.1.1,2.1-9; E16.3; E16.4; E17.1.4,2.2B,2,3, 2.4B,2.6; E17.3.3-4; E17.4.2; E18.1.1, 3.1-2,5.1; E19.1.1-3,2.2-6; E20.1.1-4; E20.4.1; E20.6.0-1; E21.1.1-5; E21.2. 3,3.1,3.4-5,3.8-9,3.12; E23.2.1,3r; E24. 1.1, 2.1,3-4; E24.6.1; E25.1.1; E26.1,2.

It is our feeling that the people who wrote these standards did not realize the impact they could have upon manufacturers of electronic equipment. We feel, therefore, that they will be happy to see our new electronic standards and I predict that they may be incorporated, almost as written, into the JIC Standards.

R. B. Colten
Process Development Section
General Motors Technical Center
Detroit, Mich.

Wanted: bound reprints of Digital Series

TO THE EDITOR—

I have followed your Digital Series with much interest during the course of its presentation in CONTROL ENGINEERING.

Since the digital material presented constitutes excellent reference information, I would like to know if any consideration is being given to making the Digital Series available in reprint form or in the form of a bound booklet. I would be willing to pay a nominal charge for this digital information in a more convenient form.

John R. Stoltz
Sperry Gyroscope Co,
Sunnyvale, Calif.

Yes, we have plans for reprinting the Digital Application Series (14 articles) as a bound volume. It will be available early in October at a single copy price of $3.00. The 13 articles in the Digital Basics Series will be re-edited and published in book form by the McGraw-Hill Book Co. in '58. Single copies of most of the 27 articles are still available from our Reader Service Dept. at 25¢ apiece. Ed.

first.

Burroughs is first with the full power of a giant electronic computing system at half the cost...the Datatron 220.

First too, a medium-priced system with a full magnetic core memory, increasing productivity 10 to 15 times over previous systems. Designed for *both* scientific computation and business data processing. Delivery of the Datatron 220 will begin during the 2nd quarter of 1958. For a summary of its benefits, write to Dept. O, Pasadena, California:

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ElectroData DIVISION

BURROUGHS CORPORATION

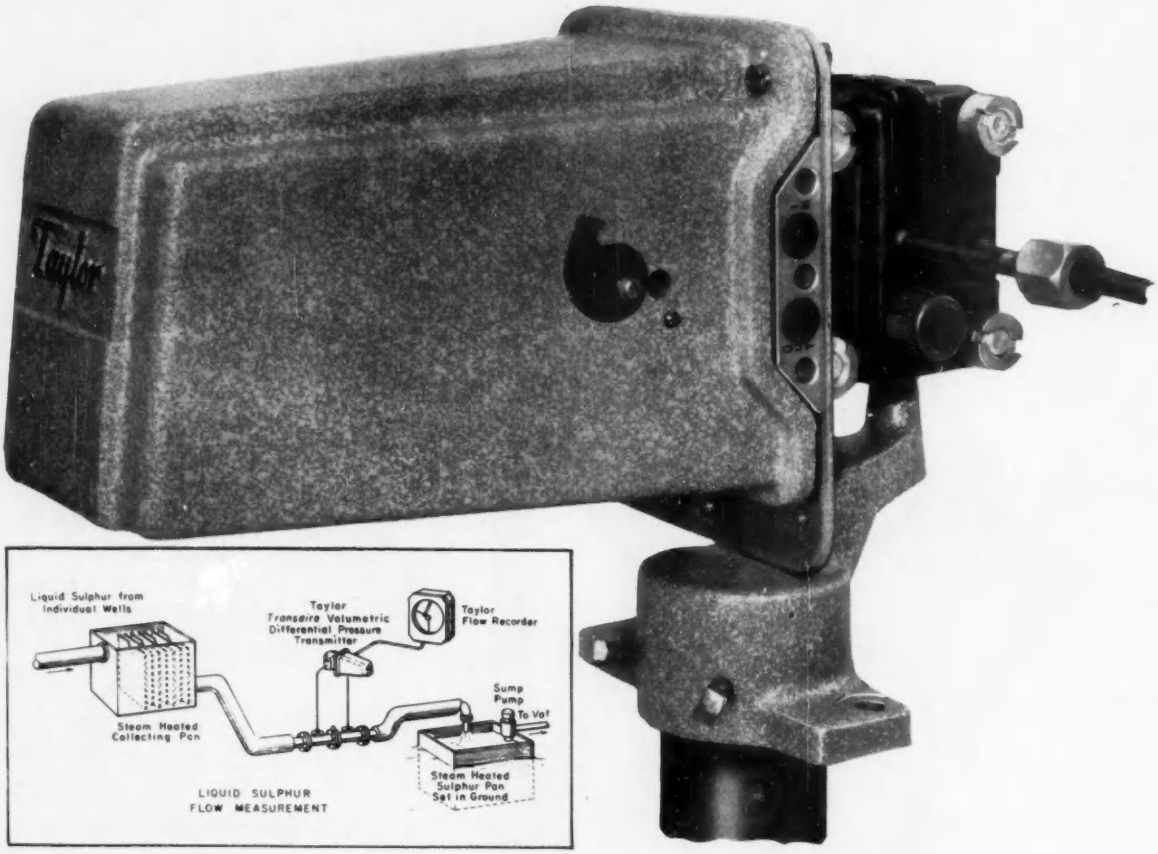
GRAPHIC • MECHANICAL • ELECTRO-MECHANICAL • ELECTRONIC SYSTEMS

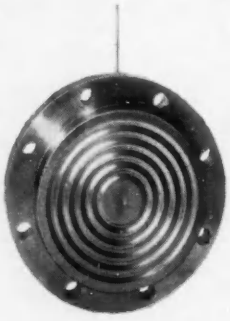
extending the usefulness of man's mind

~~SEAL~~ ~~PROBLEMS~~

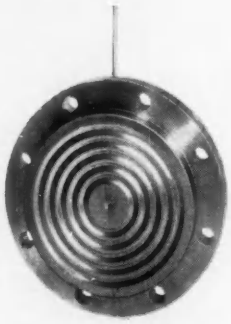
~~PURGE PROBLEMS~~

ELIMINATES





Type 95 flange, for use with chemical tee. For flow installations where diaphragm is flush with inside of pipe, so that process fluid imparts a scouring action. Also for liquid level applications where diaphragm should be flush mounted.



New Taylor Volumetric Differential Pressure Transmitter

PURGE, SEAL PROBLEMS ECONOMICALLY!

Ideal for these difficult flow and liquid level measurements:

- Slurries
- Corrosive liquids
- Colloidal suspensions
- Fluids that jell when not in motion.

The new Taylor 205T Volumetric Differential Pressure Transmitter is completely isolated from the process material. Thus it never has to be purged of deposited material, never suffers from corrosion. The pressure-sensitive diaphragms may be installed flush with the inside of the pipe or tank in a variety of mountings. The temperature limit is 300° F. at the diaphragms. Pressure limit of the instrument is 1500 lbs., and the system is limited only by the flange rating on the primary side.

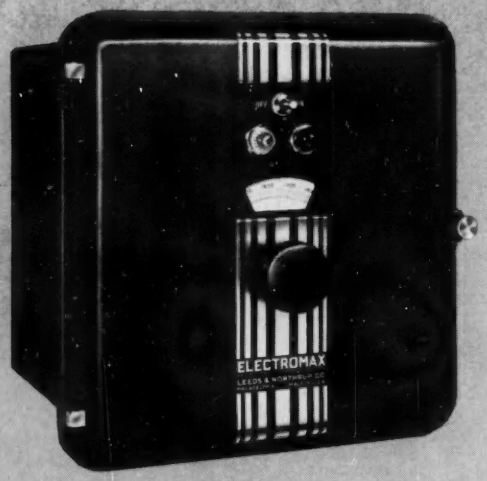
This instrument is a modification of the familiar Taylor 333RD differential pressure transmitter, and is just as accurate, sturdy and dependable. For full details about this new instrument, ask your Taylor Field Engineer, or write for **Bulletin 98281.** Taylor Instrument Companies, Rochester, N. Y. and Toronto, Canada.

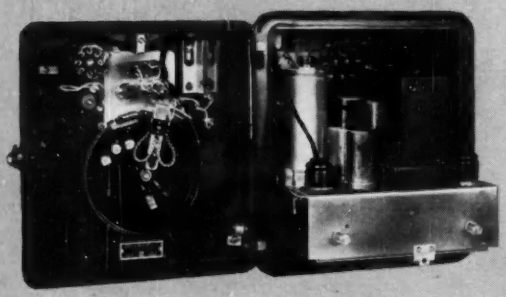
Taylor Instruments
MEAN
ACCURACY FIRST

VISION · INGENUITY · DEPENDABILITY

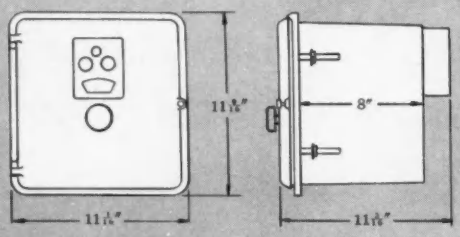
Wafer type sensing element, for use with Standard 3" ASA flange, where diaphragm need not be flush mounted with process. For example, corrosive flow or liquid level measurement or colloidal suspensions. Standard diaphragm material, for both types, 316 Stainless steel, Hastalloy B, nickel.

NEW





Design simplicity minimizes maintenance; sturdy components resist normal shock and vibration. Precisely calibrated slidewire and circuit resistors hold stability. For easy servicing, amplifier slides out of case; standard vacuum tubes are used . . . their replacement requires no special selection.



Compact Electromax controller mounts flush in panel. Leads are brought to terminal board located on back of case. Net weight about 27 pounds.

Thermocouple Electromax® Controller for temperatures up to 3200 F

- ***0.3% LIMIT OF ERROR***
- ***10 μV* CONTROL DEAD BAND***
- ***CONTINUOUS STANDARDIZATION***
- ***4-WEEK DELIVERY***

**0.5 F for base metal thermocouples; approximately 1.5 F for platinum thermocouples.*

Combining all the accuracy and reliability of a modified d-c potentiometer with a drift-free amplifier detector, this new Electromax signalling controller provides low-cost electronic two-position control where a record or continuous indication is not required. It's ideal for many electric and fuel-fired furnaces, ovens, plastic extruding machines, and some types of chemical processing units. Other uses include zone control on continuous ovens and kilns, and excess (overheat) temperature cutout control.

This compact signalling controller has only two moving parts—a plug-in relay and converter (chopper). These, together with simple circuitry and liberal use of plug-in components (including a plug-in amplifier), minimize maintenance and reduce initial cost. To speed start up of your process, Electromax is delivered four weeks after receipt of your order.

Other standard features include both thermocouple and amplifier fail-safe, and automatic reference junction compensation. Amber and red signal lights indicate whether process temperature is above or below set point.

For additional information on the thermocouple Electromax, call your nearest L&N office or write 4918 Stenton Ave., Philadelphia 44, Pa. Ask for Preliminary Data Sheet ND47-33(1).

LEEDS Instruments **NORTHRUP** Automatic Controls • Furnaces

L. T. RADER **harnesses electronics for control**

There used to be a firm conviction that electronic gear would never infiltrate industrial control. Electronic tubes made it too unreliable, too expensive. But today, control engineers turned electronic engineers have punctured that myth. They are developing electronic equipment that is every bit as dependable as the electromechanical gear it is replacing and the cost is downright competitive.

Typical of these new practitioners of electronic control is Louis T. Rader, the lanky Canadian-born PhD who heads up General Electric's Specialty Control Dept. at Waynesboro, Va. Rader spent ten years working on conventional industrial control projects before he plunged into electronics.

Since 1953, when GE's Specialty Control Dept. was created, "Doc" Rader and his engineers have helped "rewrite" the definition of electronics. "It no longer means the branch of physics that treats solely of electron tubes," enthuses Rader, "now it's that branch of engineering that starts with small signals and converts them into useful work."

"Historically," he says, "you could do anything with electronics—but at a cost. Now we are reaching the point where electronics can do the job cheaper and more dependably." To do this, Rader sees a combination of electronic gear with mechanical relays, like those specially designed for aircraft service. "Because aviation requirements are so severe, these relays will stand up exceptionally well in industrial applications where the users want complete reliability."

Machine tool control is one area for which Rader predicts a big future for electronic controls. He's formed an interesting concept to justify the use of numerical controls. "Numerical control will be economic," he says, "in industries that demand big expenditures of engineering time *per unit produced*. It probably won't pay off in something like automobile production where the units are manufactured in millions, but it will make a lot of sense in fabricating a product such as an airplane."

Lou Rader has been making a lot of sense since he graduated from the University of British Columbia with a BSEE in 1933. He went to California Institute of Technology to earn his MS and PhD degrees, and while there traveled in a group that has turned out a flock of outstanding control personalities: Si Ramo (CtE, Sept. '57, p. 19), Dean Wooldridge, J. W. McRae (head of Sandia Corp.), John R. Pierce ("traveling waves" expert at Bell Laboratories) and Howard Griest at Hughes Aircraft.

In 1937, fresh out of Cal Tech, Rader joined GE as a test engineer. After completing the company's advanced engineering program he was assigned to

what was then the Control Div. His work centered around extensions of his doctoral studies: he probed the secrets of arc suppression and conducted research into arc-resistant materials, both aimed at boosting the life of relays and contactors. During this period, Rader wrote almost 20 high level technical papers. One of the most significant reported and analyzed five or six ways of treating inductance, opening new areas in a subject that engineers had previously thought they understood pretty well.

In 1945 Rader left GE to become head of the Electrical Engineering Dept. at Illinois Institute of Technology. But the lure of industrial control drew him back to GE two years later as manager of the Control Div. engineering laboratory. Later he was made manager of engineering and in 1953 was appointed general manager of the newly created Specialty Control Dept.

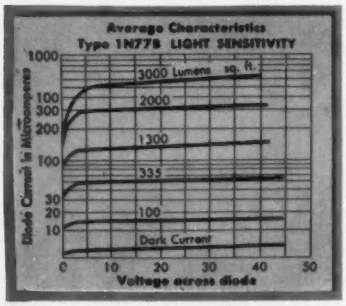
Rader's two-year stint at Illinois Tech mirrors the deep interest he has in education and school systems. Most of his outside interests concern young people in one way or another. He frequently counsels high school students who are not sure of the kind of career they want. And he's active in the Boy Scout movement as a member of the Executive Board of the local area council.

One of the key points in the philosophy that Rader imparts to both students and his engineers is that design work can't be conducted in a vacuum. It's this belief that has shaped the guiding concept at Waynesboro—"You can't just hang controls on a machine." Rather, Rader says, the system has to be designed in close rapport with the machine designer to provide optimum value and service. And that's the approach that Rader says is cutting out a niche for electronic controls in today's industry.

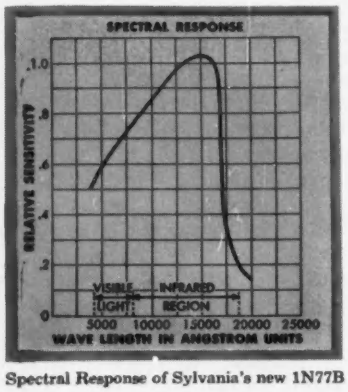
New Sylvania Photodiode

Type 1N77B

. . . puts tinier beams



Light sensitivity of the new Sylvania photodiode, type 1N77B



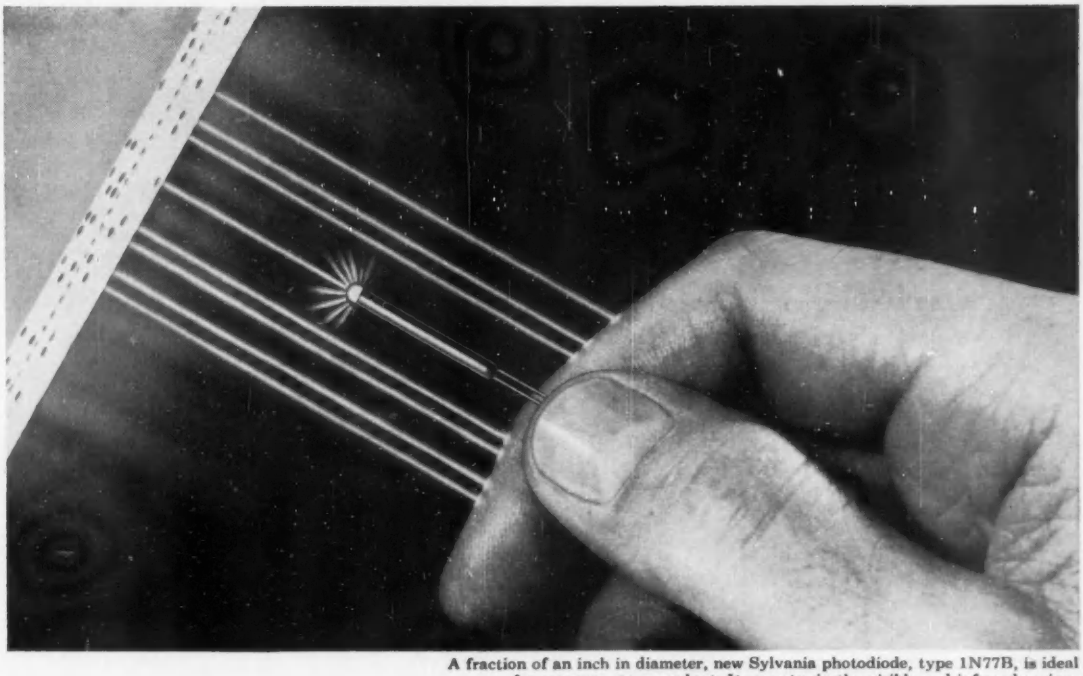
Spectral Response of Sylvania's new 1N77B

Sylvania designs a smaller photodiode with improved capabilities to handle applications where space is limited

Sylvania, leader in diode development, introduces the 1N77B, a new smaller junction photodiode with superior power dissipation and higher temperature capabilities. The improved unit, with a diameter of .077 inch, is ideal for highly compact assemblies and other applications where space is at a premium. The new 1N77B, which replaces type 1N77A, is now available at substantially lower prices in volume quantities.

The compact construction and fast response of the Sylvania 1N77B make it ideal for rapid, highly sensitive scanning and reading applications, such as in computer tape or punched cards readout. The new unit is also readily

"Sylvania—synonymous with Semiconductors"



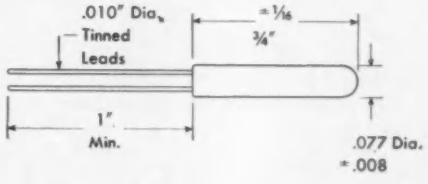
A fraction of an inch in diameter, new Sylvania photodiode, type 1N77B, is ideal for computer tape readout. It operates in the visible and infrared regions

of light to work

adaptable to infrared detection and heat-seeking devices because it is sensitive to light wave lengths extending from near ultraviolet into infrared. Other applications for the new 1N77B include liquid level control, headlight and street light dimmers, intensity controls, photoelectric controls and motion picture sound pickup.

Sylvania's improved photodiode has a higher lumen intensity than other types and a high output impedance. This is especially advantageous when coupling into vacuum tube or grounded collector transistor circuits. The new units are hermetically sealed in glass with a built-in lens that focuses light on the sensitive portion of the junction. The light interruption frequency response of the 1N77B photodiode is flat from 300 cycles to 15 kc at 100 percent with 260 lumens/sq. ft.; R_L - 110,000 ohms, —45 v.

Contact your Sylvania representative for further information on the new 1N77B.



Sylvania's new photodiode, type 1N77B, is nearly 20 percent smaller in diameter than type 1N77A which it replaces

TABLE OF RATINGS & CHARACTERISTICS

Absolute Maximum Ratings (at 25°C):

Operating Voltage	50 volts dc
Ambient Temperature (Maximum)	75°C
Power Dissipation	40 Milliwatts
Forward Current	10 Ma dc

CHARACTERISTICS

Reverse Current—Dark (E_R = -10 volts)	15 ua max.
Reverse Current—Dark (E_R = -50 volts)	100 ua max.
Noise Voltage—Dark (E_R = -45 volts, R_L = 100,000 ohms)	15 Millivolts max.
Light Sensitivity	18.7 peak-to-peak volts—min.
Light Sensitivity	37.5 peak-to-peak volts—max.
Typical Minimum Frequency Response	15.0 KC

SYLVANIA

SYLVANIA ELECTRIC PRODUCTS INC.
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LIGHTING • RADIO • TELEVISION • ELECTRONICS

The Russians Step Up the Pace in Industrial Control

When Mr. Heumann went to Russia as a U. S. delegate to the Moscow meeting of the International Electrotechnical Commission, he had the opportunity to visit plants, development laboratories, industrial exhibits and schools. We asked him, as a specialist in industrial control, to report his impressions of what the Russians were doing in industrial control for CONTROL ENGINEERING's readers.

G. W. HEUMANN
General Electric Co.

Russian engineers are committed to a Herculean task: catching up with Western technology in industrial control in the shortest time possible. A tour of Russian facilities last summer provided visitors with an impression of tremendous activity along carefully prepared lines. The present status:

- ▶ emphasis on training engineers; education is continued through a unique world-wide information gathering service.
- ▶ priorities in technical areas deemed specially important (such as ICBM missiles as described on page 30); but a willingness to copy Western technology in other areas.
- ▶ manual motor starter control is prevalent in manufacturing plants; but a transition to magnetic control has started.
- ▶ widespread use of magnetic amplifiers in the feedback control of adjustable dc drives.
- ▶ a complete absence of electronic controls using electronic tubes; photoelectric controls are practically never used—but . . .
- ▶ heavy emphasis on the use of nuclear energy for industrial control.

Educational activities indicate the hectic pace the Russians have set for themselves. Each year some 50,000 engineers are trained at college level (U. S. expects to graduate 34,000 engineers this year; then 30,000 per year for the next three years). Teachers give an impression of competence, and laboratory and demonstration equipment in the schools is excellent. Staffs of technical translators review, abstract, or translate the technical publications of the world, channeling this information into a nation-wide system of documentation which enables Soviet engineers and scientists to inform themselves on the state of the art in any area.

In their effort to build up their economy and to industrialize their country, the Soviets have assigned priorities to engineering effort in various fields. Some areas are considered worthy of major effort by engineers to expand the frontiers of knowledge, to engage in original development work, and to surpass the West. In other areas, Soviet engineers are satisfied to assimilate the technology of the West, to learn all of the West's technology, but no major effort is made to invest capital, time and talent in new developments.

When the last five-year plan was launched in 1955, Premier Nikolai Bulganin told engineers they should not be too proud to copy the designs of others, if such designs were adequate for Soviet needs.

• **Priority for energy**—In the electrical engineering field, top priority has been given to the establishment of a system of generating, transmitting and distributing electric energy. Ambitious plans are under way to expand power facilities, and a majority of engineering graduates are channeled into power plants and power apparatus development and design.

Power utilization equipment, on the other hand, does not rate such high priority. Soviet planners are satisfied to maintain old equipment in running order. The economic incentive for plant modernization to reduce costs and to stay competitive in a free market has been lacking. This may change when the decentralization plans are consummated, a program aimed at establishing competition between plants within the borders of the Soviet Union.

A visit to several manufacturing plants making electrical apparatus produced an impression that equipment is old, machines are individual units, and manual control is prevalent. Much of the machinery came out of Germany after the last war, and there is some American equipment dating from the 1930's still being used. Also in use were a few magnetic starters, and one master-switch operated magnetic controller for a rod mill.

The bulk of the motor controllers were manual across-the-line starting switches for small motors, face-plate starters and drum switches for larger motors. The controllers, although old, looked well-kept and apparently see quite a bit of maintenance. The manufacturing plants looked orderly, housekeeping was good, and the products created a well-built and workmanlike appearance. To American visitors it seemed that the Russians have acquired the necessary know-how to run industrial machinery, and to run it competently.

Although we did not have an opportunity to inspect a modern manufacturing plant, we saw evidence that a transition to magnetic control has taken place. The laboratories of the Moscow engineering school contain ample and excellently equipped facilities for students to test motors and magnetic motor control. In addition

to the working apparatus, there were numerous exhibits of control devices, some assembled, some exploded, for use in teaching control techniques to the students.

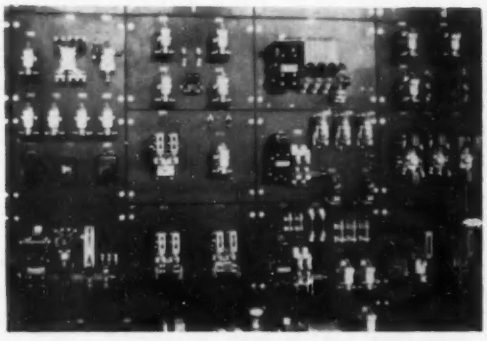
Examples of magnetic control apparatus are maintained at a permanent industrial exhibition which has been established on the outskirts of Moscow to show the most modern Soviet machinery to foreign and domestic visitors. One key display is a magnetic control device (see box).

• **No motor breakers**—As far as motor branch-circuit protection is concerned, Russian practice follows lines similar to our own. We noted the absence of "motor protective breakers" which are widely used in Europe. Instead, the functions of motor overload and fault protection are segregated and handled by separate devices. Molded-case air circuit breakers were exhibited in various frame sizes with dual-element thermal-magnetic trips.

Three lines of fuses are used. Small fuses are plug-type, following European industrial practice. Larger fuses look like NEC fuses with round barrel and blade-type connectors. We also saw a line of high-interrupting capacity fuses containing strands of silver wire embedded in silicate powder, and assembled in a ceramic body. In appearance, these fuses resembled German designs.

We did not see any industrial regulators but we saw components for use in them. We saw stacked-core type saturable reactors and metallic rectifiers, and we were told that magnetic amplifiers are used for feedback control of adjustable-voltage dc drives. Russian guides said that rotating amplifiers are used for the same purpose. The saturable reactors on exhibit were of comparatively small size, probably

Soviets Turn to Magnetic Control



Inspection of this panel indicates that Russian control engineers have followed the same basic principles which have influenced American control designers. The exhibition panel consists of slate bases, supported on angle iron framework braced to the rear wall. Many devices are bench-assembled as a unit, and live studs may be used as supports to the insulating base. Most devices shown are not suitable for mounting on steel. The panel is wired in the back with varnished-cambric insulated wire having an outside flame-resistant braid, flat-wired, cleated to the base. The wiring job is neat with straight runs and 90-degree bends. Molded terminal boards with cap-screw type connections are used for out-going control leads.

There are two lines of dc contactors. One is a general-purpose line using a "broken-back" armature. Single-pole and multi-pole forms with and without blowouts are shown. This design is used up to the equivalent of size 2. Larger contactors are heavy-duty mill-type single-pole contactors, the largest one exhibited is the equivalent of size 7. These contactors are heavily constructed, the armature rocking on a knife-edge bearing. Dc accelerating relays are definite-time type, the timing being obtained by flux decay. The same relay carcass is also used for single-pole and multi-pole auxiliary relays, with or without blowouts.

Three lines of ac contactors are built. Small contactors, used on control panels and in individual starters, are vertical-lift type, and they seem to be built up to size 2. In the larger sizes there are two lines. A general-purpose line of shaft-type contactors with sleeve bearings was seen in sizes 3 to 5. A heavy-duty line in sizes 4 to 6 resembled a German design, and these contactors are intended for use on mill auxiliaries. The existence of this line of mill-type ac contactors indicates that the Russians follow the European practice of powering mill auxiliary drives with ac motors in many cases where American practice would prefer adjustable-voltage dc drives.

For motor protection, single-pole, indirectly heated, bimetallic thermal overload relays are used. These relays are so arranged that they can be assembled on ac contactors, or separately mounted. Interchangeable nichrome heaters coordinate relays and motors. A tripping curve exhibited in one of the laboratories indicated that the relay characteristics resemble those of equivalent U. S. built relays. The permissible stall time is of the order of 20 seconds. For small motors inherent protectors are used consisting of a molded round box housing a temperature-responsive snap-disc.

Pushbutton units look much like U.S.-built heavy-duty units. They are assembled in surface-mounted or flush-mounted stations. Indicating light units may be included in the stations. For use on control desks, there are flush-mounted master switches with vertical shaft and pistol-grip handle. For heavy mill and crane duty there are surface-mounted master switches with horizontal shaft and vertical handle, double-break bridge-type contacts being actuated by interchangeable cams cut to obtain desired contact-closing sequence. —G.W.H.

RAMBLINGS ON INSTRUMENTATION

Are manufacturers' representatives human?

Everybody knows that manufacturers' representatives are (1) uneducated and technologically incompetent, (2) interested only in making a buck, (3) unfamiliar with the products they sell. In order to confirm these hoary generalizations we conducted a survey of our sales force (all independent manufacturers' representatives, incidentally). Somehow the results *don't* support the above conclusions; to wit:

64% of the sales and service personnel of our representatives have college engineering or science degrees (BSME is the most popular degree). Almost without exception those who do not possess formal college degrees have taken or are taking extensive night and correspondence courses in engineering and science subjects. Nearly 20% are Registered Professional Engineers.

70% belong to at least one engineering or industrial society (ISA was the most popular with ASME second). Of this "joiner" group one out of three (35%) has served his society in some elective office (e.g. Section President, Board Member, National Delegate, etc.). Of course, our most glittering example of society service is Judd Vollbrecht of Energy Control Company, New York, who is just completing his term as National President of The Instrument Society of America.

A surprising number are also involved in community and fraternal activities like JC's, Chamber of Commerce, Rotary, Boy Scouts, Elks, Masons, K of C, etc.

On top of this, a check of attendance records at our Product and Service Training Schools here in Michigan City and Regional Sales Refresher Courses throughout the country reveals that the salesman or serviceman gets training from factory personnel at least once every two years, frequently more often. Furthermore, in order to keep you posted on our products and their performance, he must read reams of "poop" (catalogs, service tips, instructions, installation stories, etc.) which spew forth from "the Factory" every week as well as put up with (and maybe learn something from) the Hays engineers who visit his territory at the darndest times.

All in all, this adds up to a picture of an "average" (and they hate this term) Hays' representative as being a pretty well educated guy who not only works hard at making a buck but also finds time to (a) keep learning on a regular basis about the products he sells (b) help advance technology through society activity (c) make his community a better place in which to live.

Did it just happen that we have this kind of personnel working for both you and us? No—it has taken a lot of effort alone and in co-operation with other manufacturers in a venture called Industrial Marketing Associates.

I'll elaborate more on IMA next month.

Incidental Intelligence (Toward-One-World Division)

We just learned of the experiences of a group of engineers who built a limited vocabulary computer for fast translation of English to Russian and vice versa. Seems the boys decided to feed in English phrases for translation to Russian, then requested the computer to re-translate to English. First test was the phrase "The spirit is willing, but the flesh is weak"—it came back "The ghost is ready, but the meat is raw." Next they tried "out of sight, out of mind" and became much more sympathetic with Mr. Dulles when the following spewed forth—"Invisible Idiot."

Phil Sprague Jr.

President

THE HAYS CORPORATION • MICHIGAN CITY, INDIANA

WHAT'S NEW

of several hundred watt capacity. We did not see large power-stage type magnetic amplifiers.

There was a complete absence of electronic control utilizing electron tubes. We saw no electronic motor controllers in schools, laboratories, or industrial exhibits. We also noted a complete absence of photoelectric controls. The only device employing a photoelectric tube we saw was an instrument for grading pelts for sheen, utilizing the degree of reflection of light by the pelt.

• **Atoms for control**—Some very interesting applications of the use of nuclear energy for industrial control purposes were shown at the industrial exhibition as part of an exhibit on "the peaceful use of the atom". The developments shown illustrate the use of radioactive isotopes for measurement and control.

One exhibit showed equipment for counting soda bottles on a conveyor. A radiation beam emitted from a capsule containing radioactive material is directed across the conveyor to a receiver. When a bottle intercepts the beam, the receiver responds and generates a control signal. On this application the radiation beam is used in the same manner in which we use the interception of a beam of light for photoelectric counting.

Two other exhibits demonstrate the gauging of the thickness of material. One machine is intended for thin materials, and a roll of cotton tape is given as an example. The other machine is intended for thick materials, and a strip of linoleum serves as an example. Since both machines were enclosed and sealed, we could not inspect the working parts but a guide explained that both machines measure thickness by measuring the absorption of the beam of radiation. The resulting signal can be used for indication and inspection, or for controlling the process machinery.

Another application concerns marking. The problem: to grade steel with an indelible mark which permits later identification and sorting. A spot of irradiated material is welded to the steel, the characteristic of its radiation being coded to the grade of steel. When this grade of steel is placed in a reader, the indication on a radiation receiver identifies the grade of steel.

The appearance of the control apparatus we had an opportunity to inspect was neat and workmanlike. It gives the impression that Russian engineers are competent to design and apply magnetic control equipment.

How magnetic tape converts blueprints to parts

From numbers to metal without templates or models

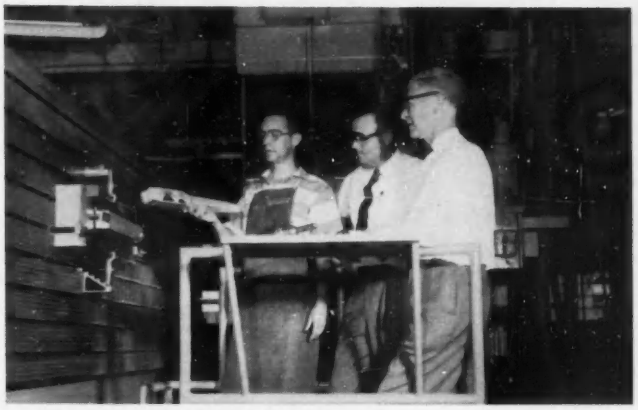


Photo Courtesy of Lockheed Aircraft Corporation

This part was made with "production tooling" that cost less than conventional machining on a single sample. The "tooling" was a reel of magnetic tape programmed from blueprints by computer and electronic director. In a kind of machine-shop black magic, the part sprang into being on a Giddings and Lewis Numerically Controlled Milling Machine. Much larger parts are also similarly made on this same mill.

NOW AT WORK IN ACTUAL PRODUCTION

This is not just a futuristic experiment. A commercial version has been delivered to a number of manufacturers. The first, at Lockheed Aircraft Corporation, produced 96 different complex parts in its second month of operation. Lockheed is using the tape-controlled mill to improve tolerances, eliminate human error and cut machining costs – often by over 50% ($21.32 versus $69.50 per part on one item). It is used for cams, templates and other intricate tooling – also for production parts on Lockheed's supersonic F-104 "Starfighter."

From initial experience at Lockheed, tape-controlled machining shows promise of reducing lead time from drawing board to production of parts by 60 to 70 percent. Since the "complete sets of tooling" are reels of tape, they can be stored as neatly as a row of books. Additional production runs can be made with a minimum of setup.

Earlier, at the Giddings and Lewis factory, tape-controlled milling was used to make one-of-a-kind cams and templates for tracer-controlled machines. Cost on a competitive bid basis was less than 50% of that for same work by conventional means. Ironically, this intricate tooling is what numerical control will eliminate wherever it supplants tracer-controlled machines.

A SIMPLE WAY TO HANDLE A MILLION COMMANDS

For the numerically controlled mill, magnetic tape provides 200 commands per second, each defining exact tool positions in three linear coordinates (angular coordinates too, on some). A minimum signal commands only 0.000125 inch of tool motion. One reel of tape programs up to 1½ hours of machine time.

These closely spaced commands are ideal for a self-correcting system of servo controls. Also they eliminate need for expensive computing and interpolating equipment at the individual machine. Centralized programming can make tapes for many machines and is not tied to the time-consuming repetitions of actual production.

With its fourteen tracks, a one-inch magnetic tape has ample reserve for extra functions. Six are used for tool-position coordinates. The others control start, stop, coolant, and even voice instructions for impending tool change. Tracks can even be shared by several functions, allowing still further expansion.

Control tape on an Ampex FR-100 can hold over 1 million commands for each axis of tool movement

We will be glad to furnish more facts on magnetic tape recording and its use in machine tool control. Write Dept. HH-8.

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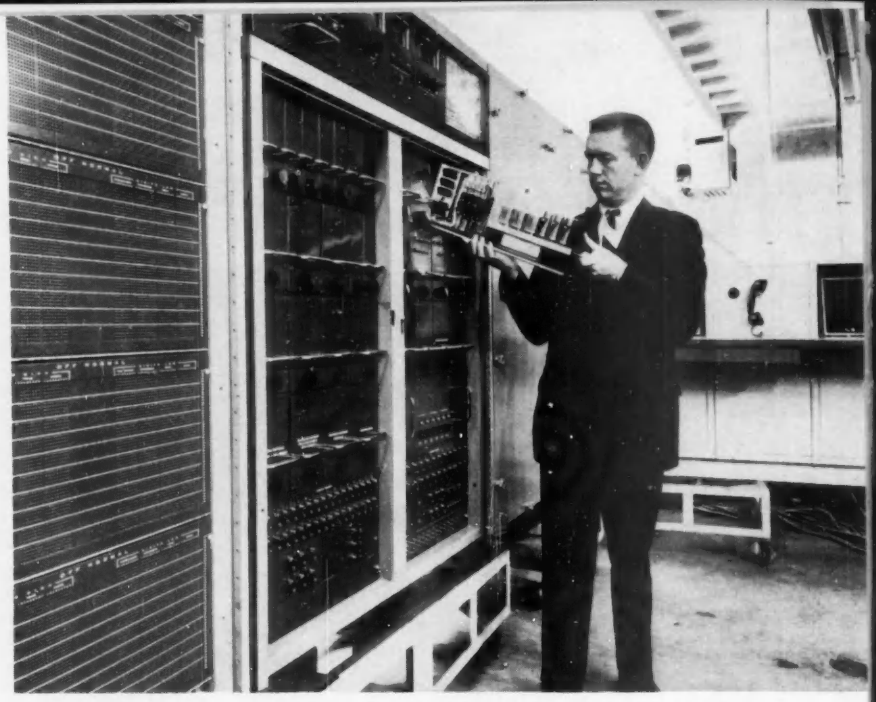
Texas ethylene plant installs first transistorized data logger. It improves reliability, but its high cost raises question of how to justify installation. One answer: use the data logger to boost process yield.



Pinboard programming (foreground) and modular design (engineer is removing a typical one) impart a high degree of flexibility to data processing system.

TRANSISTORIZED DATA LOGGER:

Reliability—but at a Price

Critics of automatic data logging equipment will be watching closely this month when the world's largest ethylene cracking and purification unit starts operating with a new kind of automatic data logging equipment. Designed to answer the complaint of lack of reliability, the new information system—a Beckman 112—represents the first automatic data logger installation based entirely on semiconductor and magnetic core circuitry. It will monitor continually and log periodically up to 400 points (temperatures, pressures, and flow-rates) at the Phillips Chemical Co.'s new Sweeney, Tex. ethylene plant.

One of the big obstacles to wide user acceptance of automatic data logging systems has been reliability (CtE, Jan. '57, p. 21). Users say that two key trouble spots are the electronic vacuum tubes and the stepping switches.

• **99.9% continuous operation**—In the Beckman 112 system, the vacuum tubes have been replaced by transistors, crystal diodes, and magnetic core amplifiers. Stepping switches are hermetically sealed and immersed in dielectric oil to boost life and decrease the maintenance problem.

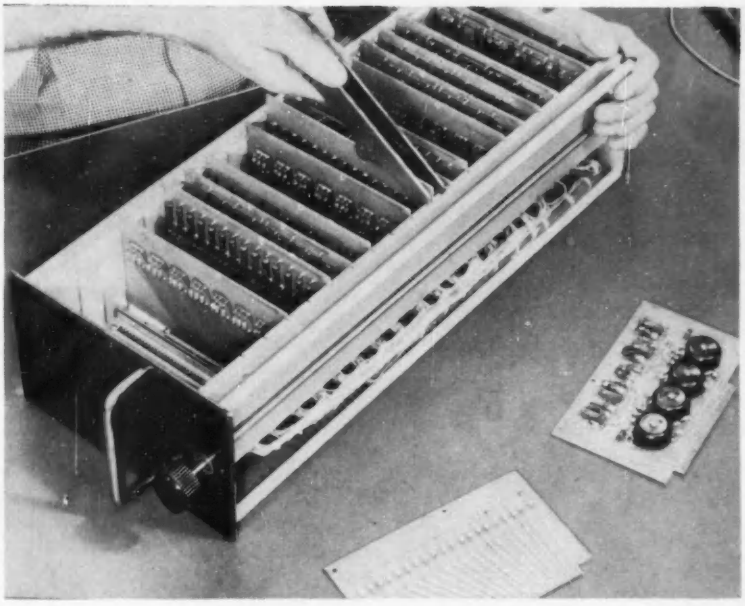
The Beckman logger will assuage another user gripe: the need for specially skilled electronics maintenance men. Beckman has packaged the data system so that process-plant instrument technicians can perform necessary maintenance—all the system's components are mounted on standardized plug-in circuit boards. Troubleshooting techniques are aimed at narrowing the source of trouble to a single board, which can then be replaced as a unit. Beckman claims the new system will perform 99.9 percent continuous operation.

The plant instrumentation associated with the data system includes 168 pressure gages that measure both pressure and flow (by the differential pressure method), 200 thermocouples that measure temperatures ranging from minus 200 to nearly 2,000 deg F, and stream analysis instrumentation.

• **Backup instrumentation**—Although Phillips is betting over $100,000 that the Beckman system has the answer to data logger reliability, the chemical company is still not using the data system as a super-controller for the entire plant. The Sweeney control room—said to be one of the most modern in the world, with green-tinted windows through which operators get a panoramic view of the plant—contains a secondary instrumentation system based on 200 display instruments and multirecorders. This backup arrangement includes 70 controllers tied into minor control loops that by-pass the data system.

However, one of the major objectives that Phillips has set for the logging equipment is to increase the yield of the ethylene-making process by supplying information to operators that will give them closer control of process variables. Design capacity of the Sweeney facility is over 200 million pounds of ethylene gas per year, stored at 1,500-lb pressures in underground salt caverns. The chemical company thinks that even a small percentage increase in yield will pay for the logger in less than a year.

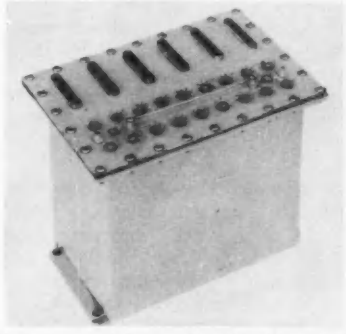
• **More than a logger**—The feature



Plug-in circuit boards narrow troubleshooting routines so instrument technicians can perform maintenance.

that Phillips is counting on to do this is the big computing capacity that Beckman has built into the 112 system, capacity that is easily programmed through pinboards. Key to optimum ethylene making, Phillips thinks, is flow rate at various places in the process. But to be meaningful, these gaseous flow rates have to be compensated for temperature and pressure (feed stock is ethane, propane or butane gas).

The Beckman 112 first compensates the flow rates, then monitors the computed result. Warnings supplied by the data logger as variables stray off normal limits will alert plant operators to take action to bring the offending variables in line. With the close control Phillips expects to cut down on losses from two sources: hydrocarbon molecules that are never cracked to ethylene, and molecules that are cracked too far to unusable product.



Scanning module can handle 50-inputs.

Heart of this watchdog scanning operation is a group of input switching modules, each one capable of handling 50 input channels. The 50-channel module is the basic building block of the system and contains its own preamplifier and program pinboard. To prevent "ground loops"—spurious signals originated by differences in ground potential between the sensing element and the data system—the scanning module "floats" with the sensing element: it is never directly connected to the balance of the data system.

• **Built-in computer**—Computation is accomplished primarily by analog devices, operating at high speed with a minimum of electrical hardware. Programming, storage, and readout, however, are all in digits. And the equipment can take up to three inputs from digital computers or instruments.

An element that Beckman claims helps build reliability is a specially designed analog-to-digital converter, a high-speed transistorized switching network that measures incoming analog signals to an accuracy of one part in a thousand in less than 1/100 sec.

From a design standpoint, the most conspicuous feature of the 112 system is the modular assembly, based on functions rather than hardware. This lends a high degree of flexibility to the equipment. For example, there is a square-root module that can be left out of the system without hindering operations if no square roots have to be calculated. If requirements change in

the future, the square root module can be added at anytime.

• **A new problem**—The reliability and greater flexibility of the Beckman 112 go a long way towards answering criticisms raised against automatic data loggers. But the same features that dampen criticism of reliability give rise to still another weakness. Design for reliability and flexibility costs money. The higher cost of such data loggers makes it that much harder to justify the initial installment.

Users are apparently handling this conservatively by using automatic data loggers in big installations where it is possible to rack up big savings by improving the process or yield, savings that can pay for the logger in a short time. The Phillips installation is the second big installation in recent months to rely on data logging equipment for efficient operation. The other: Tidewater Oil Co.'s new 130,000-barrel-per-day refinery, in which refinery management is counting on automatic data logging equipment to keep the installation running efficiently (CtE, June '57, p. 24).

Just how well the Beckman 112 serves the Phillips installation can go a long way to answering some of these questions. It's another reason why eyes of instrument men are being focused on Sweeney, Tex. In the balance could be the solution to the conundrum: reliability versus the cost of reliability.

Fireflash Missile Uses Electronics and Pneumatics

When Britain took the wraps off the production air-to-air missile, Fireflash, observers noted that its guidance system combined electronic and pneumatic hardware. Using electronic techniques for initial guidance—the missile brackets a radar beam laid on the target by a parent aircraft equipped with a simple permission-to-fire computer—Fireflash system transmits electronic inputs into electro-pneumatic valves to actuate pneumatic pistons that trim the four rudders.

Operating at speeds of Mach 2, the Fireflash is being built by Fairey Aviation Co.'s Weapons Div.

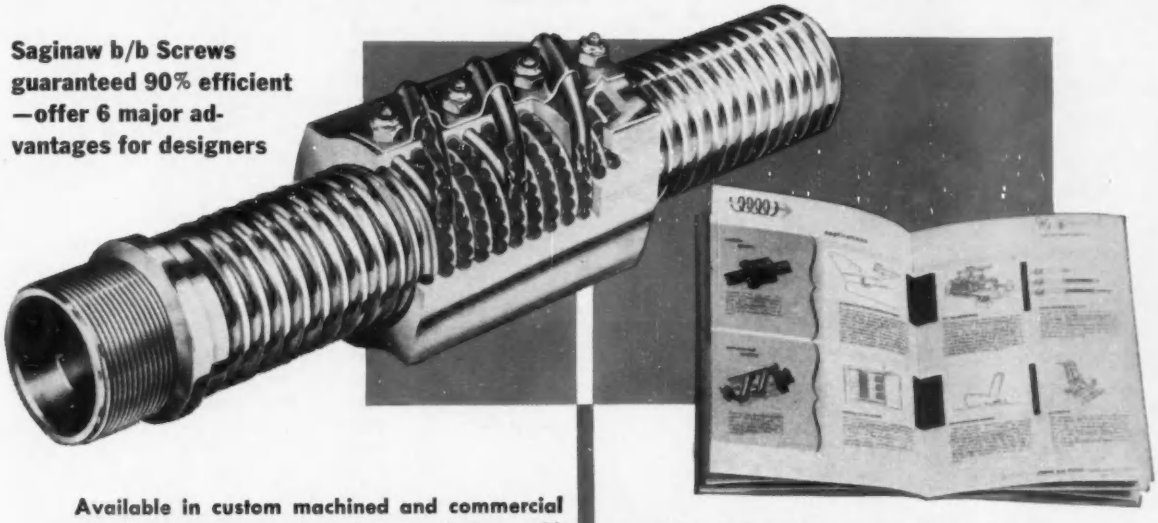
•

Hydraulic components made by Flick-Reedy's new manufacturing plant will be cooled and heated by the U. S.'s biggest heat pump. Using rainfall as source of water for the air-conditioning equipment, the $540,000 multistage pump will provide year-round conditioning for 220,000 sq ft.

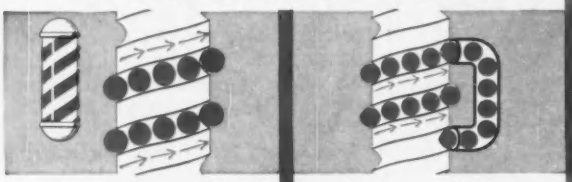
ACTUATION PROBLEM too tough for ordinary devices?

SAGINAW CAN HELP YOU SOLVE IT!

Saginaw b/b Screws guaranteed 90% efficient —offer 6 major advantages for designers



Available in custom machined and commercial rolled thread types—have been built from 1½ inches to 39½ feet long—⅜ to 10 inches diameter.



Nut *glides* on steel balls. Like stripes on a barber pole, the balls travel toward end of nut through spiral "tunnel" formed by concave threads in both screw and mating nut.

At end of trip, one or more tubular guides lead balls diagonally back across outside of nut to starting point, forming closed circuit through which balls recirculate.

1 VITAL POWER SAVINGS. With guaranteed efficiency of 90%, Saginaw b/b Screws are up to 5 times as efficient as Acme screws, require only ⅓ as much torque. This permits much smaller motors with far less drain on the electrical system. Circuitry is greatly simplified.

2 SPACE/WEIGHT REDUCTION. Saginaw b/b Screws permit use of smaller motors and gear boxes; eliminate pumps, accumulators and piping required by hydraulics. In addition, Saginaw b/b Screws themselves are smaller and lighter. Units have been engineered from 1½ in. to 39½ ft. in length.

3 PRECISE POSITIONING. Machine-ground Saginaw b/b Screws offer a great advantage over hydraulics or pneumatics because a component can be positioned at a predetermined point with precision. Tolerances on position are held within .0006 in./ft. of travel.

4 TEMPERATURE TOLERANCE. Normal operating range is from −75° to +275° F., but assemblies have been designed in selected materials which function efficiently as high as +900° F. These units are practical where hydraulic fluids have lost efficiency or reached their flash point.

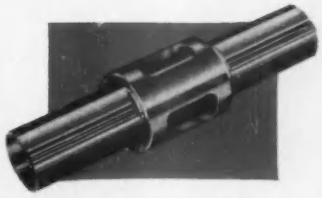
5 LUBRICATION LATITUDE. Even if lubrication fails or cannot originally be provided because of extreme temperatures or other problems, Saginaw b/b Screws will still operate with remarkable efficiency. Saginaw units have been designed, built and qualified for operation without any lubrication.

6 FAIL-SAFE PERFORMANCE. Far less vulnerable than hydraulics. In addition, Saginaw offers three significant advantages over other makes: (1) Gothic arch grooves eliminate dirt sensitivity, increase ball life; (2) yoke deflectors and (3) multiple circuits provide added assurance against operating failure.

YOUR FREE COPY OF THIS NEW b/b SCREW AND SPLINE "PROBLEM SOLVER" SHOWS HOW

36 pages crammed with time-, work-, and money-saving facts: Principles • Types • Basic Operations • Coupling Methods • Efficiency • Advantages • Selection Factors • Design Data • Sample Problems

SAGINAW b/b SPLINE



● Averages 40 times lower coefficient of friction than ordinary sliding splines!

Utilizing the same basic *gliding ball* principle, Saginaw has developed the *Saginaw b/b Spline* which radically increases the efficiency of transmitting or restraining high torque loads.

It can be fitted with integral gears, clutch dogs, bearing and sprocket seats, etc. Units have been built from 3 inches to 10 feet long—⅜ to 6 inches in diameter.

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or see our section in Sweet's Product Design File

Saginaw ball bearing Screws and Splines

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WHAT'S NEW

ICBM Success Upgrades Soviet Missile Technology

The Soviet Union's announcement of a successful ICBM test firing shocked the general public, but missile engineers around the country were not surprised by the news. In Washington, government intelligence agencies had been aware of Soviet ICBM prototype launchings for at least four months. At missile design installations, engineers had known that the Russians were doggedly concentrating every resource on the development of a long-range ballistic missile.

None of the engineers that CONTROL ENGINEERING contacted doubted that the test had been completed. As one British engineer put it, "The USSR rarely overcalls its hand in the aviation and missile field."

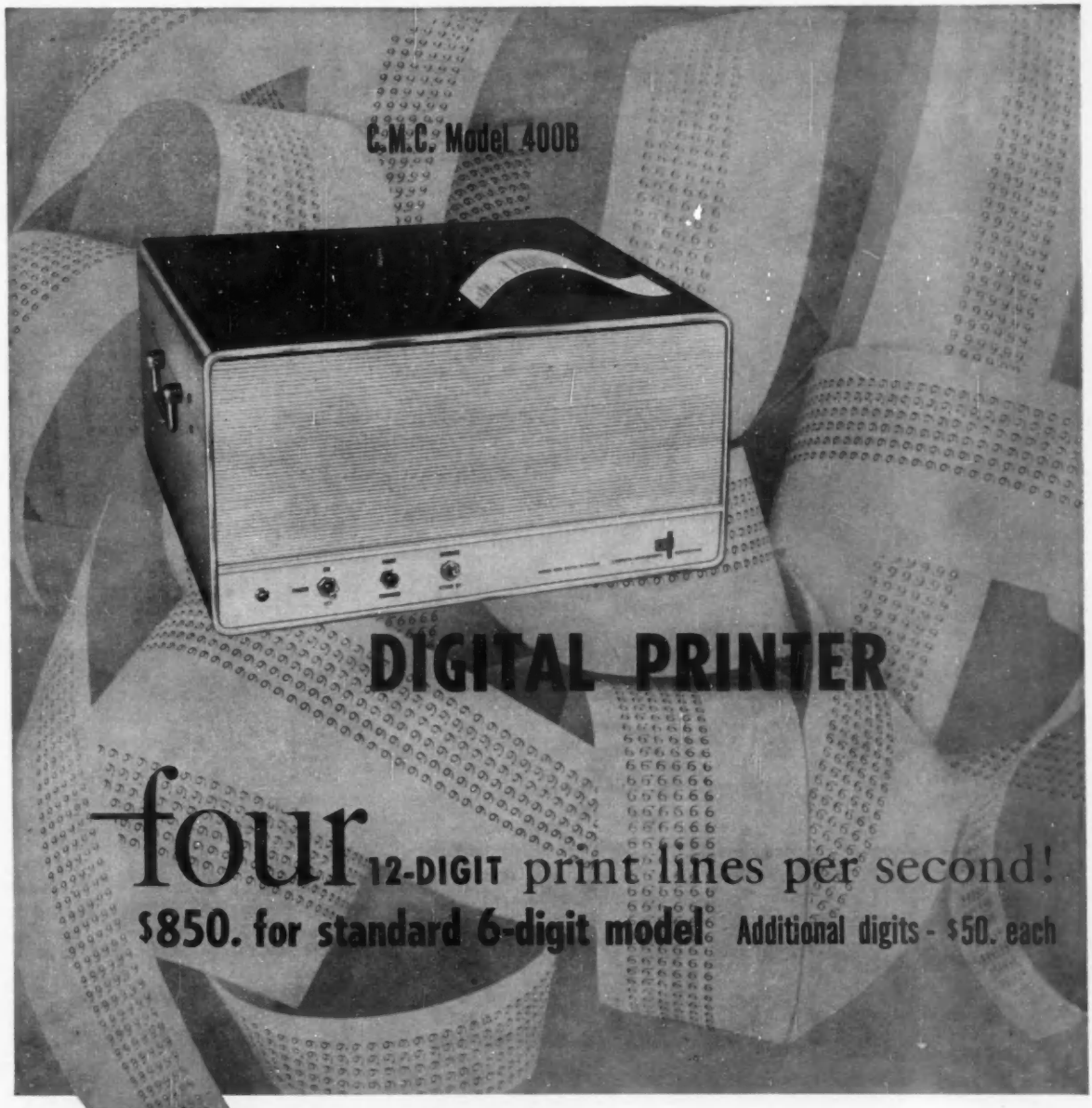
The big questions that the test generated were: 1) How far are the Russians from volume production of an operational ICBM? and 2) How much precision have they achieved in their controls and guidance systems? British engineers offered the typical feeling when they answered the first with, "We only wish we knew." However, there's been plenty of deduction and some substance to answer the second.

• **Ballistic systems**—One missile engineer told CONTROL ENGINEERING that the Russians have based their work 100 percent on ballistic systems as far as long range missiles are concerned. They use the premise that the missile must leave the earth's atmosphere to travel at incredibly fast speeds and extremely long ranges. They've practically ignored "air breathers" or pilotless planes.

Another engineer with contacts in Europe said that the Russians were stressing standardization. They apparently are working on three types of ballistic missiles, (in addition to a souped-up version of the German V-2), a 600-mile missile, a 1,500-mile missile and a 5,000-mile missile. All three, he said, are purported to have similar guidance systems, power plants and propellants. The Russian ICBM (designated T-3 or M-104) is believed to use the same subsystems developed for the shorter range (1,500 miles) IRBM (designated T-2 or M-103)

Both here and in Britain, engineers agreed that the control system for the Soviet ICBM was undoubtedly an inertial guidance system, probably similar to the one that will go in the Russian IGY satellite.

For fuel, the Russians appear to be



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CC-62

WHAT'S NEW

concentrating on liquid propellants. They are probably using more powerful rocket engines than those the U.S. plans. The T-3 ICBM is supposed to be a two-or three-stage vehicle—each rocket being of nearly equal power (U.S.'s IRBM Atlas reportedly has a single liquid-propellant engine with two boosters). The Russian IRBM is supposed to be powered by a first-stage rocket engine with 245,000-lb thrust and a second-stage motor with 77,000 lb.

Washington experts believe that current missile progress in Russia is built on native scientific talent, under the direction of Chief Marshall of Aviation N. F. Zhigarev and Army Marshall N. D. Yakovlev. They say that in recent years, the Soviets have cut their dependence on captive German brain power.

• **Mechanics' role**—British engineers and German missile scientists working for the U.S. don't agree with the Washington premise. They say that the Russians captured some scientists and virtually all the German missile mechanics. And the mechanics, engineers feel, may be the key to the Russian success. It's no secret that one of the knottiest problems is getting the hardware to work. Good mechanics are the most important ingredient in a missile shoot, particularly on a prototype, missile testers say.

Despite the success of the Russian ICBM, engineers feel that U.S. design techniques are probably ahead of the Soviet's. Sharp evidence: Russian missile hardware is bulkier than American. Atlas, for example, stands about 65 ft without the boosters, weighs about 100 tons. The Russian T-3 ICBM is believed to weigh up to 150 tons and to stand 160 ft high.

As a result of the success of the Russian ICBM, the race to launch the first earth satellite has become hotter than ever. In the balance is the claim to undisputed leadership in the field of long range military missiles.

British To Build Ceramic Thorium Reactor

Britain's Atomic Energy Authority plans to study properties of thorium as a nuclear fuel in high temperature, gas-cooled reactors. General Electric Co. has been awarded a contract to build a zero energy assembly for an experimental reactor.

The thorium, in ceramic form (probably as carbides) is expected to permit raising the operating temperature of the reactor to 1,400 deg F.

Shown at Bell Laboratories, Murray Hill, N. J., are, left to right, F. J. Herr, S. T. Brewer, L. R. Snoke, E. E. Zajac and F. W. Kinsman.

They're wiring the seas for sound

These five Bell Labs scientists and engineers may never "go down to the sea in ships." Yet, they're part of one of the most exciting sea adventures of modern times. Along with many other specialists, they are developing the deep-sea telephone cable systems of the future.

Here's how they join many phases of communications science and engineering—to bring people who are oceans apart within speaking distance.

F. J. Herr, M.S., Stevens Institute, is concerned with systems design and analysis. He studies the feasibility of new approaches and carries out analysis programs to select optimum parameters for a proposed system design.

S. T. Brewer, M.S. in E.E., Purdue, communications and electronics engineer, explores new designs for sea-bottom amplifiers needed to step up power of hundreds of simultaneous telephone conversations.

L. R. Snoke, B.S. in Forestry, Penn State, is the team biologist. He investigates the resistance of materials to chemical and microbiological attack in sea water. Materials are evaluated both in the laboratory and in the ocean.

E. E. Zajac, Ph.D. in Engineering Mechanics, Stanford, is a mathematician. He studies the kinematics of cable laying and recovery. Cable's dynamic characteristics, ship's motion, the mountains and valleys in the ocean bottom—all must be taken into account.

F. W. Kinsman, Ph.D. in Engineering, Cornell, solves the shipboard problems of storage, handling and "overboarding" of cable. New machinery for laying cable is being developed.

Deep-sea cables once were limited to transmitting telegraph signals. Bell Labs research gave the long underseas cable a voice. New research and development at the Labs will make this voice even more useful.

BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

WHAT'S NEW

Automatic Landing System Goes to Sea

"The system is locked on, the plane is now on automatic control." This announcement signaled the start of the first press-witnessed fully-automatic carrier landing, aboard the USS *Antietam* in the Gulf of Mexico. Controlling the plane was the Bell Aircraft Automatic Carrier System designed to permit full scale carrier operation under adverse weather conditions. Moments later a Navy F3D twin-jet SkyKnight came roaring in for a touch-and-go landing, completely unassisted by the pilot who kept his hands clasped over his head until the plane had rolled to a stop.

Responsible for this deft landing was a closed loop system consisting of a high-precision radar antenna drive unit, a stabilization computer, and a flight path computer, all situated on the carrier's flight deck, and an airborne radio controlled data link.

In operation, the radar picks up the plane about three miles off the stern of the carrier, and tracks it continuously until the plane is landed. Data on the pitch, roll, and yaw of the ship as well as range of the plane is fed to the stabilization computer to be converted into a set of coordinates. These are then transmitted to the flight path computer, where they are compared with a programmed position. The computer determines the error in the plane's course and feeds the corrective data to the radio controlled airborne data link, which makes the necessary corrections through the plane's automatic pilot.

Angular accuracy of the tracking radar is said to be within 1 milliradian. In fact, so accurate was the entire system that plots of three separate landings on altitude-vs.-range coordinates appeared almost as a single trace.

At present most of the equipment is housed in trailers and contains a good deal of instrumentation that will not be required in a service model. For example, the flight path computer is a standard REAC general-purpose analog computer built by Reeves Instrument. When it has been determined which functions are unnecessary, the unit will be stripped down until it contains only the functions used by the landing system.

While everyone who witnessed the landings seemed thoroughly impressed, John Loeb of the Navy's Bureau of Ships cautioned that in spite of its satisfaction, the Navy has not yet officially accepted the system.

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Raytheon Computer Transistors were developed under Signal Corps contract and are manufactured especially for computer service, on a separate production line. They are backed by five years of experience in the mass production and quality control of Raytheon Fusion-Alloy Transistors.

Maximum stability is guaranteed by rigid test procedures including ***strict process control, 100°C baking*** of every transistor, ***100% steam cycling*** to assure positive hermetic sealing.

When you specify Raytheon Computer Transistors you are also assured of:

HIGH VOLTAGE RATINGS • HIGH CURRENT GAIN
FAST SWITCHING SPEED
LOW SATURATION RESISTANCE

Here are the electrical specifications for Raytheon PNP Computer Transistors

			2N425			2N426			2N427			2N428		
Parameter	Conditions (25°C)	Units	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
BVPT		volts	−30	−50	—	−25	−45	—	−20	−30	—	−15	−25	—
V_{BE_1}	$I_B = -1mA$ $V_{CE} = -0.25v$	volts	—	−0.35	−0.45	—	−0.35	−0.45	—	−0.35	−0.45	—	−0.35	−0.45
h_{FE_1}	$I_B = -1mA$ $V_{CE} = -0.25v$		20	30	40	30	40	60	40	55	80	60	80	—
h_{FE_2}	$I_B = -10mA$ $V_{CE} = -0.35v$		10	15	—	10	18	—	15	20	—	20	30	—
$R_{sat.}$	$I_B = -10mA$	ohms	—	2.2	3.2	—	2.2	3.2	—	1.4	2.1	—	1.1	1.6
			for $I_C = -100mA$			for $I_C = -100mA$			for $I_C = -150mA$			for $I_C = -200mA$		
$f_{\alpha b}$	$V_{CB} = -5v$ $I_E = 1mA$	Mc	2.5	4.0	—	3.0	6.0	—	5.0	11.0	—	10.0	17.0	—
C_{ob}	$V_{CB} = -5v$ $I_E = 1mA$	μμf	—	14	20	—	14	20	—	14	20	—	14	20
Switching Speeds														
$t_d + t_r$	$i_C = -50mA$ $R_L = 200$ ohms	μsec	—	0.53	1.0	—	0.53	1.0	—	0.43	0.85	—	0.43	0.85
t_s	Values of i_B "on" and i_B "off" are	μsec	—	0.3	0.6	—	0.3	0.6	—	0.3	0.6	—	0.3	0.6
t_f	5.0mA for 2N425 3.3mA for 2N426 2.5mA for 2N427 1.6mA for 2N428	μsec	—	0.45	0.65	—	0.35	0.55	—	0.35	0.55	—	0.30	0.50

For all types I_C (max.) = −400mAdc average
i_C (max.) = −1000 mA peak

Dissipation coefficient in free air = 0.4°C/mw
Dissipation coefficient with radiator = 0.28°C/mw
Dissipation coefficient with infinite sink = 0.18°C/mw

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EUROPEAN REPORT

New Logic Design Means Low Cost Computer

Ferranti Ltd., British electronics manufacturer, has put a large scale scientific data processor into production to compete with American-made machines. The new electronic digital computer, named the "Mercury", will sell for slightly above the one year rental charged for large scale American computers.

Although the company claims that Mercury "is equivalent to any digital computer produced in the U. S.", a spokesman more properly put it in a class that has no American equivalent*. He said that it approaches IBM's 700 series in speed of operation but it far outperforms the 600 series.

B. W. Pollard, head of Ferranti's Computer Dept., says the Mercury is essentially for use in large scale research work. For example, one unit will be installed at the United Kingdom Atomic Energy Authority's research development at Harwell.

The price tag on the Mercury is about $280,000, including installation and some maintenance.

Key factor in the relatively low cost, says Ferranti, is the logic design of the machine, an approach originated at Manchester University. Mercury uses parallel access to the core memory but serial operation.

This design, coupled with the use of "floating point" system of number representation (meaning that the range of the answer doesn't have to be anticipated), also accounts for the high speed of operation—claimed to be 50 times faster than any present computer in Western Europe. Typical operation speeds:

addition	180 microsec
multiplication	300 microsec
division	3.5 microsec

Typical subroutine speeds:

square root	5.5 millisec
logarithm	6 millisec
exponential	4 millisec
sine or cosine	5 millisec

Although the machine divides at relatively slow speed, Ferranti engineers say it makes up for that deficiency by its high speed for all organizing instructions—only 60 microsec.

Its core memory occupies only ¼ cu ft; capacity totals 1,024 words, each of 40 binary digits. A magnetic drum of 16,000-word capacity serves as backing storage.

Full scale production will be underway by the end of this year. At that time plans call for one Mercury to be completed every six weeks; production then may be stepped up to one a month. First completed Mercury was shipped to Norway in September and limited production this year will supply additional machines for export to Switzerland and France. In addition, Ferranti has orders for seven more machines to be used in Great Britain.

* For a last minute development, see page 40.

Interkama to Show Off German Control Industry

In the 13 years since World War II ended, German industry has made a phenomenal recovery, and today, threatens to outproduce every other country in Western Europe. What part the technology of instrumentation and automatic control has played in this remarkable renaissance will be revealed in November when the International Congress & Exhibition of Measuring Instrumentation & Automation opens in Dusseldorf on Nov. 2.

The idea for the Dusseldorf Interkama built around measuring and control equipment started about five years ago with Dr. H. Pietzsch, who finally sold the idea to German instrument and control companies and NAMUR (Standard Working Association for Measuring & Control in the Chemical Industry). The heavy publicity aimed around the world in behalf of Interkama has induced manufacturers from all parts of the world to participate in the exhibit which will cover 200,000 sq ft. Technical sessions are being jointly sponsored by trade associations in the electrical, machinery and chemical processing fields.

Typical subjects taken from the Interkama program (printed in three languages to prove the international scope of the meeting):

- Electrical and Process Control Measuring Instruments and Processes of Measurement
- New Methods of Control and Their Application in Practice
- Power Control of Boilers for Compounding
- Control in Plants with Batch Processes

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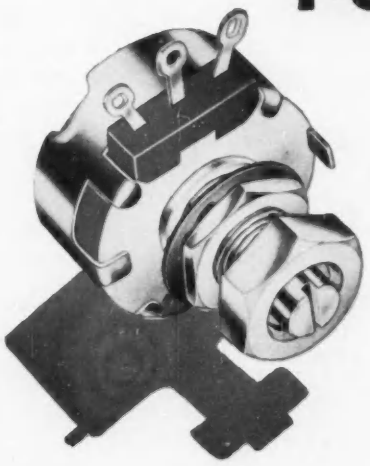

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10. No rivets. Terminals permanently molded in resistance element and control base.
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WHAT'S NEW

Bringing the Cockpit Up to Date

FORT WORTH

There's a unique instrumentation research program under way at Bell Helicopter's Fort Worth laboratories. The object of the research: to develop helicopter instrumentation that will permit such planes to fly anywhere, anytime, under all conditions of visibility with pilots who have had no special training.

Called IMHEP–Ideal Man-Helicopter Engineering Project–the program is long range with no specific date for completion and is sponsored by the Office of Naval Research in cooperation with the Bureau of Aeronautics and the Army Signal Corps.

After two years of study, the Texas researchers have isolated four major problems:

- the inherent instability of the helicopter which must be constantly attended by the pilot
- instruments designed for aircraft are not ideally suited for helicopters; one example: velocity devices used on conventional aircraft don't work too well on helicopters because helicopter speed is too low and the rotors cause excessive air turbulence
- pilots are overburdened by volume of dials that have to be read and interpreted
- shortage of information that pilot needs and/or information presented in wrong form

Bell now thinks the heart of the answer to these problems lies in computing-control (of the type described in CtE's September issue). Company engineers see the computer as "a revolution in computer circles which will process all data coming in from the sensing equipment. It will perform the necessary calculations, it will generate command signals for automatic control of certain functions, and it will feed signals in proper form to the pilot's display."

They say, "The pilot will be able to choose automatic flight if he wishes, or he will be able to fly the helicopter himself. He will be able to interrogate the computer on certain items. And the device will serve as a watchful eye warning him of impending difficulties, either mechanical or aerodynamic."

Bell's approach to other aspects of the program:

- to use various assisting devices to make the helicopter more stable. At present there are several good helicopter autopilots whose design can be incorporated into the central computer

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Input Voltage	95-130 VAC, single phase, 50/60 cycles, ±10%	**Load range**	0 to full
Regulation accuracy	±0.1%, against line; ±0.1%, against load	**Width**	17¼"
Distortion produced	3% Max.	**Height**	8¼"
Time constant	0.1 second	**Depth**	11"
		Rack mount height	8¼"
		Net weight	75 lbs.
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*Ask for data on other models and capacities.

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to provide stability augmentation with little additional cost in weight.

• to design an entirely new instrument panel that will provide the pilot with all the information he needs in a form that is easy to interpret. The computer will do automatic computation so that the pilot does decision making instead of data interpretation.

To determine what information a pilot really needs, Bell has called on a subcontractor who specializes in human engineering. First job has been to find out what elements are common to all modes of flight and which pieces are most important. Here the job of finding cues gets out of the realm of the psychologist and into that of the flight simulator. By using the simulator, engineers will test the pilot's reaction under given conditions, progressing slowly toward an optimum cockpit. The result, say engineers, will be a revolution in cockpit design.

IMHEP is similar to a project under way at Douglas Aircraft which is working on an optimum cockpit for conventional aircraft.

New Computer Design For ElectroData

Computer manufacturers, who have been revolutionizing industry's data processing procedures for the past five years, are getting set for still another major innovation. Combining floating point arithmetic with the magnetic core memory permits the design of a medium-priced, high-speed, general-purpose digital computer, comparable in performance to machines that previously cost over a million dollars.

First U. S. company to announce production of such a machine is ElectroData Div. of Burroughs Corp. Deliveries of the new Datatron 220 (approximate price: $600,000) will start in mid-1958. (In Great Britain, first delivery of a computer with a similar concept was made this month; see European Report, page 36.)

Use of the magnetic core memory, according to ElectroData, allows a computer to combine large-scale computing abilities—required for scientific problem-solving—with large volume capacity—required for business data processing. For flexibility, ElectroData will offer the core memory in units of from 2,000 to 10,000 words (10 digits plus sign), in increments of 1,000. Access time is 10 microsec.

The Datatron 220 will compute 300,000 additions or subtractions per minute; 30,000 multiplications; and 15,000 divisions.

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WHAT'S NEW

Compiling Systems Cuts Programming Time

Reductions in electronic computer programming time are promised by the Univac Flexi-Matic Generalized Programming System announced by Remington-Rand Univac Div. of Sperry Rand Corp.

The new system provides automatic programming and coding aids which are useful in programming any problem. From an input program written in Flexi-Matic Code, and a library of routines also written in Flexi-Matic, the system produces a finished running program in Univac computer code.

About 300 library routines are now available in the Univac Flexi-Matic Library, byproducts of solving problems at various Univac installations. In almost every problem, Remington-Rand says, there are elements that can be used in other problems. The Flexi-Matic system enables the programmer to isolate these elements, "generalize" them and store them in the library while solving the immediate problem.

The system is described in a 250-page manual for Univac users.

CONTROL BITS

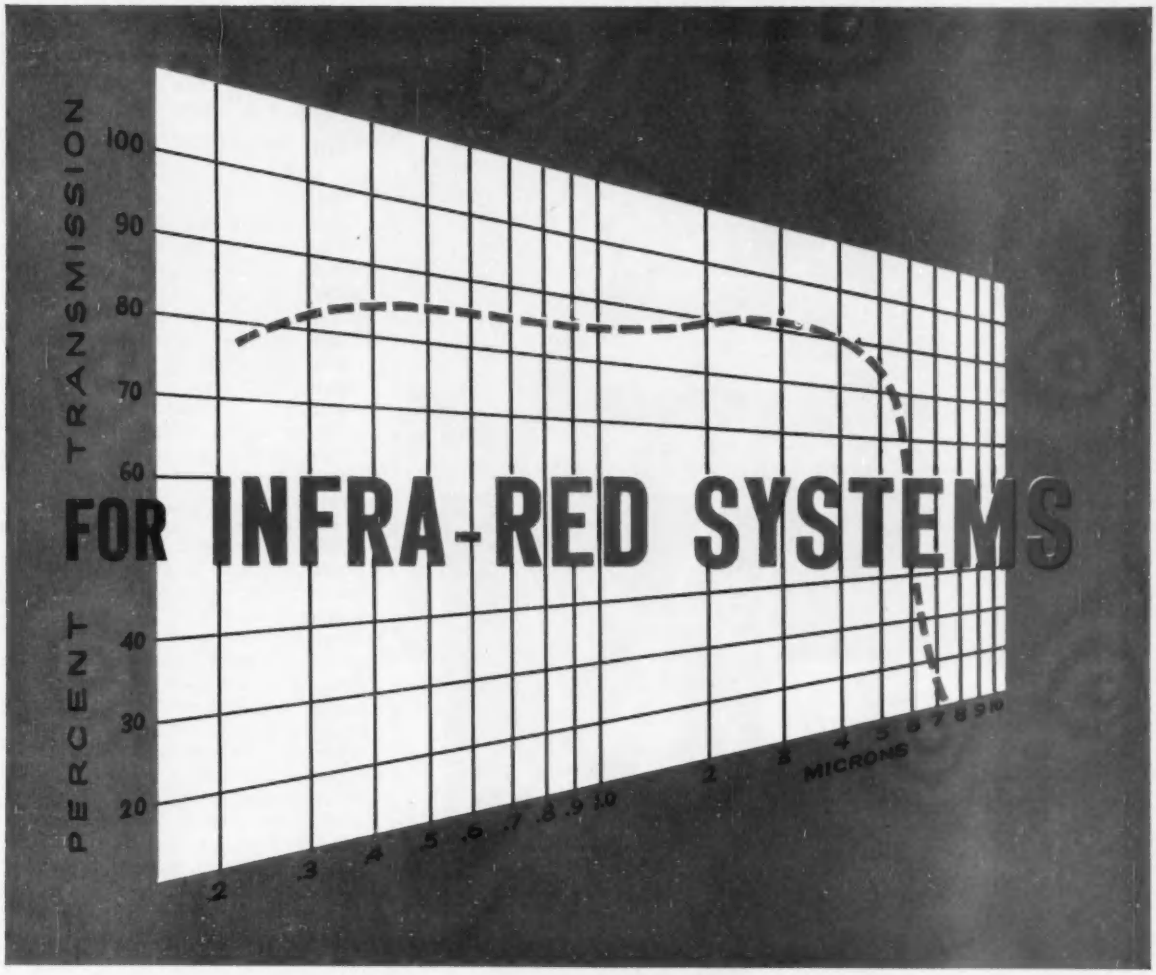
Engineers and scientists interested in atomic energy now have a dictionary to establish precise meanings of technical terms. American Standards Association and ASME have approved a 185-page volume (Glossary of Terms in Nuclear Science and Technology as an American Standard, and ASME will publish the book. Price: $5.00.

•

One of the highest peak power linear accelerators ever built will serve as the injector for the 6 billion volt electron synchrotron being constructed by MIT and Harvard University. Built by Applied Radiation Corp. the accelerator will use 5 megawatts peak power to raise electrons to a 20 mev level.

•

Applied Radiation Corp. has built another unusual particle accelerator—the first commercial Cockroft-Walton accelerator ever produced in the U. S. The 350,000 ev machine will accelerate a 400 microampere beam of positive ions when it is installed by its purchaser, the University of Arkansas. The University will use it primarily to generate a source of neutrons by bombarding tritium with positively charged deuterons.



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WHAT'S NEW

Photo Engineers Hold First Instrument Meeting

LOS ANGELES

Two years ago, the Society of Photographic Instrumentation Engineers (SPIE) was formed to foster inquiry into the field of photo-instrumentation and to promote its recognition as a science of measurement. In August, SPIE held its first symposium; but there was nothing of the neophyte in the way the session was run. SPIE unveiled a new technique in meeting presentations that kept interest at a fever pitch. Informal workshops, liberally interspersed with audiovisual techniques, replaced the usual reading of formal papers.

Morton Sultanoff, of the Aberdeen Proving Grounds Ballistics Laboratory, led one discussion by describing a progressive multiple exposure technique to increase the perception of ultra high-speed photographic test data. This technique, he explained, makes it possible to project the test record at normal cine projection rates. Previously, instrumentation data had to be analyzed on a frame basis for direct data assessment.

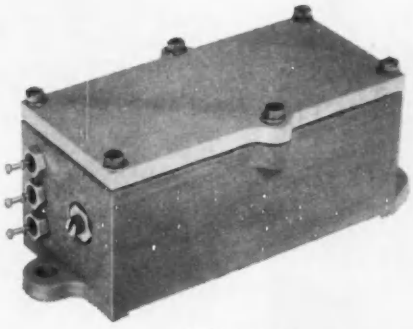
• **Systems concept**—The role of the systems concept in test programs was the topic of a workshop conducted by Ernest Stern and Donald Webber of The Ramo-Wooldridge Corp. The two engineers outlined ways to use photo-instrumentation in test programs, defined the role of photo-instrumentation as opposed to electronic and telemetry techniques, and stressed the dependence of photo-instrumentation techniques upon adequate analysis and operation.

In another session, future photo-instrumentation techniques were the topic of discussion. Among those considered: image intensification, infrared and the role electronics will take in replacing some existing photographic equipment.

Thirty-five makers of photographic instrumentation set up a display which they named "Exhiborama". One highlight was the showing by the Pacific Optical Co. of a 16 mm full color movie taken with a 168 deg lens and projected into a hemispherical bowl for viewing. —M. M.

Mathematics— Too Much, Too Little?

Despite gentle nudges from Moderator Harold Chestnut of GE, the discussion at the recent panel session on "Obstacles to Progress in Non-



A line of accelerometers has been announced by the Components Division of Fairchild Controls Corporation. The unit shown—designated Type 940—is now being built for a toss bombing control system for the U.S. Air Force. These accelerometers have been developed with the same exceptional accuracy and reliability found in the complete Fairchild line of precision components: pressure transducers; linear and non-linear, single and multi-turn potentiometers; Fi!mPots® and trimmers.

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Fairchild's new line of accelerometers will accurately measure a wide range of static or uniformly-varying types of acceleration. Applications include flight testing, air-borne telemetering and computing, and measurement of maneuvering accelerations of missiles and aircraft. Variations of conformation, G-range, natural frequency and damping can be developed to meet special customer requirements. Damping is accomplished by the viscous shear action of the mass in an oil medium.

Over-all accuracy, including linearity, hysteresis and repeatability, is better than 1.5%. The Type 940 (shown above) will operate under ambient temperatures of −55°C to 100°C and will withstand vibration in the order of 10-55cps .030" double amplitude and 55-500cps at 5G in each of the three axes. Whatever your precision component requirements, whether potentiometers, pressure transducers or accelerometers, you can rely on Fairchild's complete line and advanced engineering for the best answer. For information, write to: Dept. 140-87C, Fairchild Controls Corporation, Components Division.

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linear Control" always drifted back to mathematics. Comments from both the panel members and the floor pretty well established that advances in mathematical techniques are required to permit significant progress in the analysis and synthesis of nonlinear systems. In addition, there is the problem of educating the average control engineer to use the mathematical tools that are already at his disposal.

Some of the difficulty stems from the usual gap between mathematician and engineer: the mathematician will not recognize procedures that give the right answer (or at least an approximation to the right answer) unless it can be rigorously proven, while the engineer is not interested in the detailed rigor of the mathematician but rather in the answer.

How to overcome this dilemma created a wide-open discussion. One suggestion: set up some of these analytical and synthesis procedures in handbook form for use by less-mathematically-grounded engineers. But the objection was raised that this tended to eliminate the thought process, and besides, how does one select the right technique if one is not familiar with the capabilities of all of them? This idea led one engineer to criticize the extensive use of computers for analysis and design because it also tended to be mechanical, thus masking the real physical problems. However, this was quickly refuted by other members of the audience and panel.

Several people felt that both the societies and technical publications could advance the knowledge and use of the mathematical procedures required to handle nonlinear systems by presenting clear basic papers pointing out the background and application of these techniques.

The foregoing discussion occurred after the panel members had presented their individual thoughts on the matter at the afternoon session of the Aug. 19 "Symposium on Nonlinear Control" sponsored by the PGAC of the IRE and participated in by the Feedback Control Systems Committee of the AIEE and the IRD of the ASME. PGAC Chairman Gene Grabbe was quite satisfied with the attendance of 114 (including many of the top-notch men in the field), considering that several booby traps turned up along the way. Example: The meeting was planned on the day prior to WESCON to attract attendance without materially interfering with peoples' schedules. But it turned out that this one extra day meant

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WHAT'S NEW

staying away from the office for a whole week instead of just four days.

Prior to opening the panel sessions for general discussion from the floor, the panel members (O. J. M. Smith of University of California, George P. West of Ramo-Wooldridge, and Charles F. Taylor of Daystrom Systems) primed the pump by pointing out the obstacles to nonlinear control in their particular areas of interest.

—B. K. L.

WESCON—
San Francisco Style

For the first time, WESCON, the West Coast's big electronic show and meeting, migrated out of Los Angeles northward to San Francisco's famous Cow Palace. Although the move failed to disturb the quality of the exhibits or the technical papers, it apparently did influence the attendance, down about 20 percent from the anticipated 30,000 visitors.

Theme of this year's show seemed to be more control than communications or other branches of electronics. About 140 (of the seven-hundred-or-so exhibitors) booths displayed components and systems directly applicable to the control field; 27 advertised complete systems, and six computer manufacturers exhibited their products.

As usual, a number of manufacturers took advanatge of the concentration of technical talent to unveil new products. Among those of particular interest to control engineers and shown for the first time:

• Operational Information System by Daystrom Systems, designed initially to yield operating guides on a real-time basis. Features solid-state general-purpose computer which can be completely programmed from punched tape to accommodate process changes and pilot-plant type operations. Intended in the future for closed-loop, digital-computer process control.

• New Donner Scientific Model 3100 analog computer. This $15,000 unit has 30 stabilized operational amplifiers and facilities for interconnecting two or more of the basic computers for handling complex problems.

• New Model F Servoscope by Servo Corp. of America. Instrument provides sine, modulated sine, and square wave signals as well as the linear sweep on four ranges from 0.0005 to 100 cps.

• Kin Tel dc digital voltmeter Model 401 which uses new Industrial Elec-

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Several distinct advantages accrue when you design for a standard timer—as against making a special timer for your specific job:

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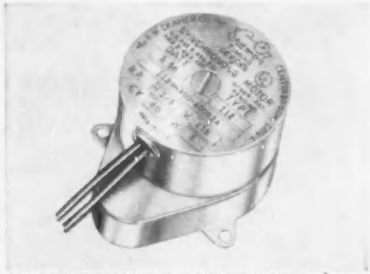
MINOR CHANGES EASY. In the event you can not find a stock or catalogued timer to meet your exact needs, discuss your problem with a full-line timer manufacturer. He will frequently be able to modify a similar unit to your specifications with only minor changes, thus saving you the costs of engineering and lengthy testing.

Only rarely will you have to specify a completely new design. And then your best approach is to talk it over with the specialists in the field of time control.

WRITE TIMER SPECS EARLY. Timer requirements should be determined early in the design process, so that an available standard timer, with the right characteristics and proved performance, can be accommodated.

LET US HELP YOU. Cramer engineers are always ready to discuss your time control problems. They can tell you about interval timers, time delay relays, cycling timers and time totalizers in 85 stock variations in the wide Cramer line. And they can handle your special needs, too. Write us or see your local Cramer representative. The Cramer Controls Corporation, Box 46, Centerbrook, Conn.



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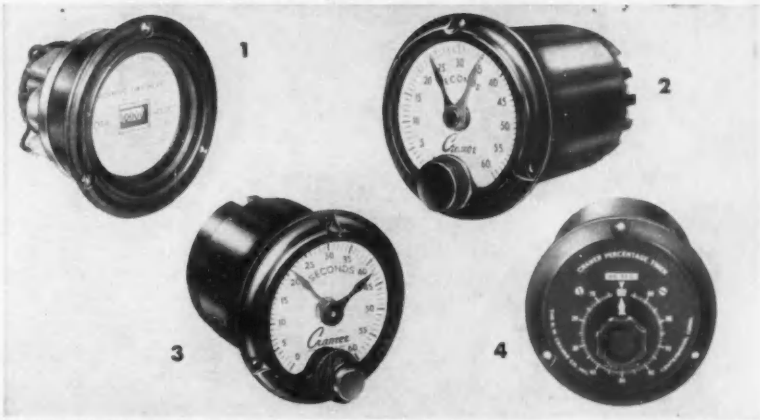
A FEW STOCK TIMERS FROM THE BROAD CRAMER LINE



1. TYPE 631E TIME TOTALIZER. Registers elapsed time on 5-digit drum-type counter. *STOCKED* in total ranges of 9999.9 and 99999 hours at 115V, 60 cps. Also 9999.9 hours at 220V, 60 cps. Other available (including resettable) types count 1/10 seconds, seconds, 1/100 and 1/10 minutes, minutes, 1/10 hours and hours. Bulletin PB-610.

2. NEW TYPE 412 TIME DELAY RELAY. Introduces timed delay between operation of control circuit and load circuit. *STOCKED* in full-scale ranges of 6, 15, 30, 60, 120 seconds; 5, 15, 30, 60 minutes; 5, 12, 24 hours at 115V, 60 cps. Also 15, 60 seconds; 5, 15, 60 minutes at 220V, 60 cps. Bulletin PB-311.

3. NEW TYPE 241 AUTOMATIC RESET INTERVAL TIMER. Provides pushbutton start, automatic and immediate reset for electrically operated equipment. *STOCKED* in full-scale ranges of 6, 15, 30, 60, 120 seconds; 5, 15, 30, 60 minutes; 5, 12, 24 hours at 115V, 60 cps. Also 60 seconds; 5, 15, 60 minutes at 220V, 60 cps. Bulletin PB-241.

4. TYPE 610 PERCENTAGE TIMER. Makes (or breaks) electrical circuit for adjustable percentage of a fixed time period. Calibrated in steps of 1% from 4 through 96. 100% setting provided. Snap action switch. *STOCKED* in ranges of 15, 30, 60 seconds; 5 minutes at 115V, 60 cps. 15, 30, 60 seconds at 220V, 60 cps. Bulletin PB-510A.

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(Formerly R. W. Cramer Co.)

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WHAT'S NEW

tronics Corp. in-line numerical display for unusual clarity of presentation. Other features: automatic continuous standard cell calibration, 100 microvolt sensitivity, 0.75 sec reading time.

• New 7100 series mechanical totalizing counter by Anatran Engineering Corp. Ten contacts or pots can be coupled to each visual indicator wheel for remote electrical indication, telemetry, or control of counter reading.

• Miniaturized sphere resolver by Vectron. Originally designed for a navigational computer, basically it transforms polar coordinates to rectangular coordinates. It can also be used as a precision variable speed drive.

• New tape-card reader Model 171 manufactured by California combines certain advantages of both tape and card techniques by simultaneously reading 10 rows of 8 holes each on standard 1 in. teletype tape. Maximum reading rate for continuous operation is 6 frames per sec.

• Epsco Low Level Differential Amplifier, Model DA-102, claimed to reduce the cost and complexity of instrumenting facilities for jet engine tests, wind tunnel vibration tests, etc.

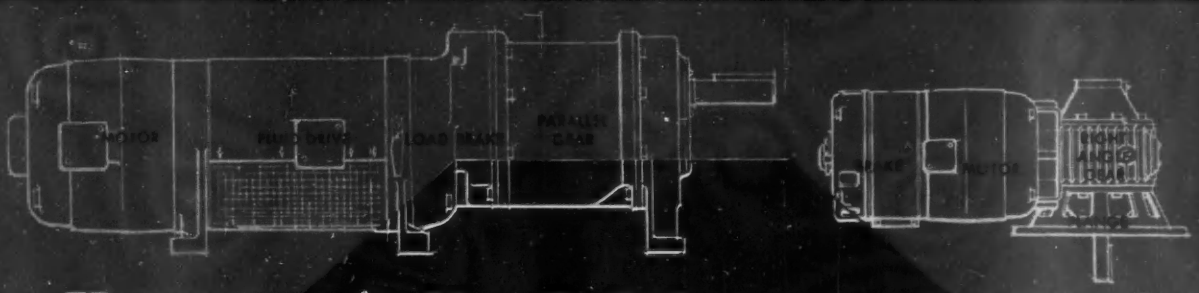
• New 100-volt germanium transistor, the DT-100 by Delco has a collector diode rating of 100 volts with high current handling ability. This is the eighth power transistor available from Delco.

One advantage of the show at the Cow Palace was the proximity of meeting rooms and exhibits, a condition that permitted visitors to move from meeting to exhibit with a minimum loss of time. The exhibit area was roomy and well organized; there didn't seem to be the hectic hustle and bustle associated with many shows of this size.

Exhibitors felt the quality of the audience was good, if a little smaller than expected. Two reasons were credited most frequently for the diminished attendance: 1) recent cutbacks and rumors of cutbacks have made West Coast companies reluctant to authorize large travel expenditures; and 2) the San Francisco area just doesn't have the concentration of large industry that furnished the bigger attendances at previous WESCON shows in Los Angeles.

The technical sessions provided a wealth of papers covering a variety of subjects of interest to the sponsoring groups, PGAC, PGEC, PGIE and others. Some of the more significant will be abstracted in future issues of CONTROL ENGINEERING.

—B. K. L.



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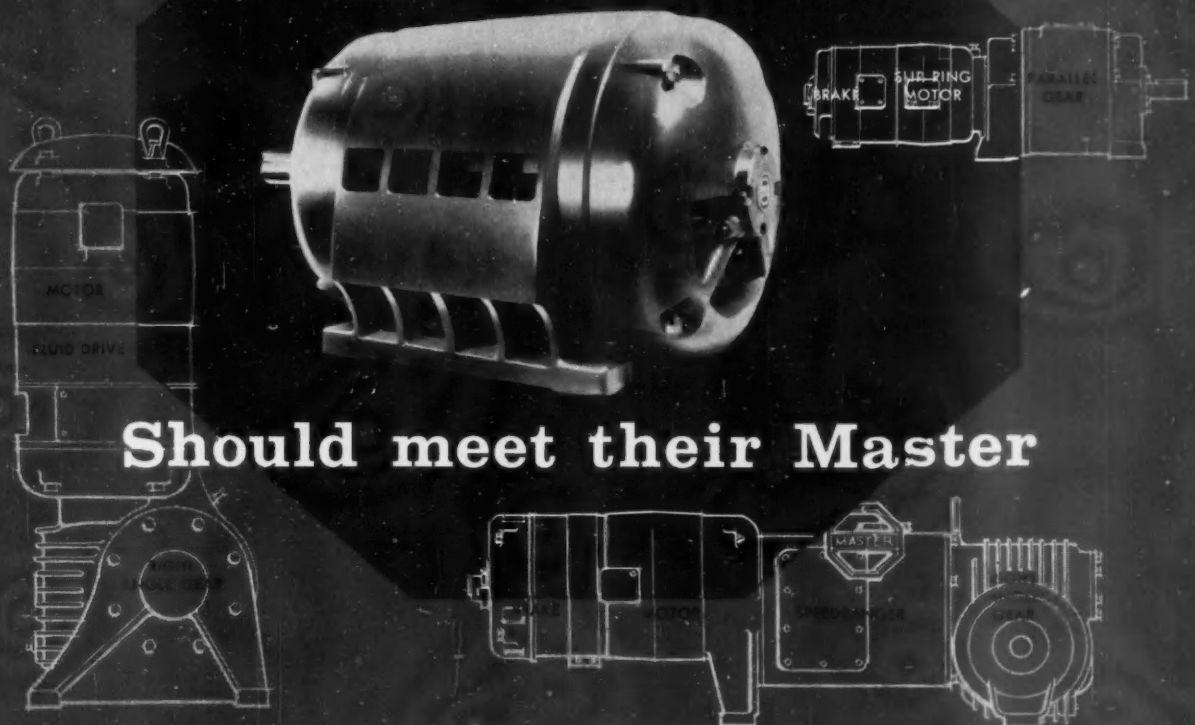

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AROUND THE BUSINESS LOOP

Six-Month Reports Look Good, Though Defense Cutbacks Cloud Future

As summer ended, control and component manufacturers anxiously peered into crystal balls trying to predict how summer defense cutbacks would affect fourth quarter business. Some sales seemed sure to sag as Congressional economy measures took hold—suppliers to the Navaho project were the first to feel the economy bite.

But overall, control companies were enjoying a good year (see chart of six-month reports below) and if there were some factors that might depress sales, there were others that were ready to nudge control sales upward.

• **Bright spots**—Widespread acceptance of data processing equipment in process control is one of the bright spots. In the past six months, automatic data loggers in industrial applications have really taken hold. Control companies feel they've solved the reliability bugaboo that was holding up acceptance by users (see "Transistorized Data Logger", p. 26). Beckman whose first data processing system started operation at a Sweeney, Tex. ethylene plant this month, says it has sold ten more installations to companies that cover such widely divergent fields as chemical processing, petroleum refining, aluminum smelting, and jet engine testing.

And at Wescon in August, Daystrom Systems announced that it was entering the data processing field with a system designed to provide industrial process information on a real-time basis. Daystrom's first installation has already found a buyer—Louisiana Power & Light—and will be delivered early in 1958.

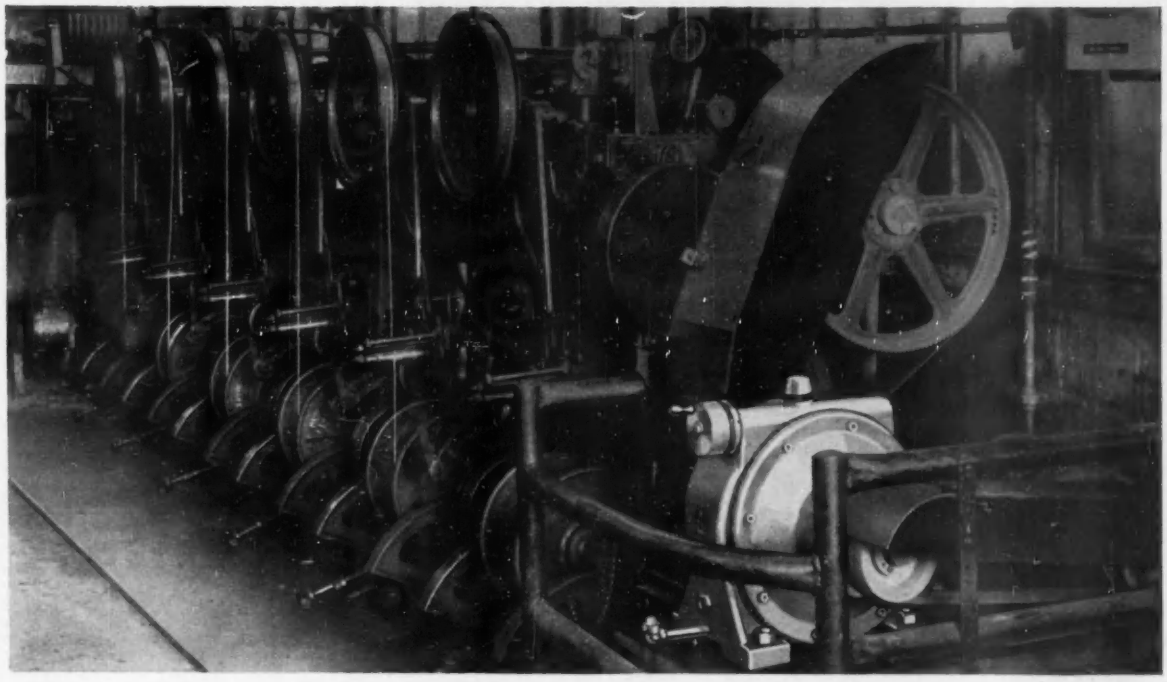
Accelerating the acceptance of such equipment in industrial applications is a steadily growing pressure, generated by the need for increased productivity in the face of rising costs and the demand for better quality. And the booming market for data processors has injected life into associated instrument and control equipment sales.

Late in August, the National Industrial Conference Board reported results of a survey in which NICB found manufacturers of instruments and control were optimistic about sales, production and profits for the rest of the year. One reason could be that capital expenditures are still rising. Over two-fifths of the reporting companies (total 205) are planning higher second-half rates of capital expenditure than prevailed in the first six-month period. Another 30 percent planned to continue spending at the same rate.

• **Defense's budget**—Many control companies are counting on this increased activity to offset sales drops

COMPANY	6 Months Sales 1956 (millions)	6 Months Sales 1957 (millions)	Percent Change	6 Months Net Profit Percent Change
Amphenol Electronics Corp.	$12.9	$15.8	+ 22.0	+ 50.5
Consolidated Electrodynamics	10.8	15.2	+ 40.6	+ 60.4
General Precision Equipment	74.1	93.3	+ 25.6	+130.0
G. M. Giannini & Co.	4.7 (a)	5.6	+ 18.2	+ 11.5
Litton Industries	14.9	27.7	+ 91.5	+ 71.6
Metals and Controls Corp.	17.3	19.6	+ 13.0	— 16.0
Midwestern Instruments	1.7	3.5 (b)	+105.2	+206.0
Norden-Ketay Corp.	10.2	13.8	+ 35.0	*
Servomechanisms, Inc.	7.3	10.1	+ 39.8	— 66.5
Siegler Corp.	15.4 (c)	32.7 (c)	+113.1	— 1.7
Square D. Co.	48.4	50.7	+ 2.5	— 14.4
Standard Coil Products	28.7	27.2	— 5.3	*
Texas Instruments	19.3	30.8	+ 60.0	+ 67.0
Victoreen Instruments	1.6	1.7	+ 4.2	*
Westinghouse Elec. Corp.	606.1 (d)	982.9	+ 62.3	*

(a) Based on first 28 weeks of 1956.
(b) Includes merger with Magnecord, Inc.
(c) Annual totals for year ending June 30.
(d) Affected by long strike.
* Profit in first half of 1957 compared to loss in first 6 mos. of 1956.



CLEVELAND SPEED VARIATOR

winds 4 reels of cable simultaneously—where old drive slipped with 2 reels

THIS machine winds tin-plated wire used in the manufacture of cable. The Cleveland SpeedVariator on it replaced a drive of the same capacity with which there was slippage and frequent maintenance.

With the new Cleveland, it was immediately possible to run simultaneously 5 reels of the heaviest wires, as compared to only 2 with the old drive. In fact, the 10 HP drive motor soon proved unequal to the 5-reel load which the Cleveland was handling without slippage. Now driving 4 reels of the heavy wire, the machine is doing double the work it formerly handled.

Wherever you need a variable speed drive, consider Cleveland. Write for Bulletin K-200. The Cleveland Worm & Gear Company, Speed Variator Division, 3260 East 80th Street, Cleveland 4, Ohio.

Note these major advantages of the Cleveland Speed Variator

1 An extremely compact unit, with input and output shafts in line and rotating in the same direction.

2 Operable at any input speed up to 1800 rpm—either clockwise or counterclockwise rotation.

3 Rated for constant horsepower output over a 9:1 or 6:1 range; or for constant torque over a 6:1 range.

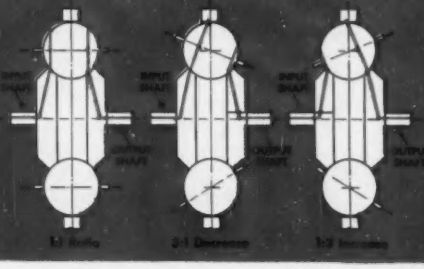
4 Infinitely variable output speeds over the entire range of adjustment.

5 No slippage—positive, automatic torque adjustment in direct proportion to the loads encountered.

6 Ample bearing support on both shafts for overhung pulleys.

7 Long life and minimum maintenance through absence of belts and complicated linkages.

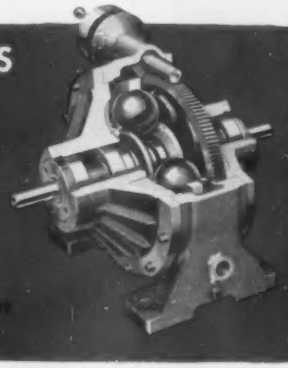
HOW THE CLEVELAND SPEED VARIATOR WORKS



Power is transmitted from input shaft to output shaft through alloy steel driving balls which are in pressure contact with discs attached to the two shafts.

Relative speeds of the shafts are adjusted by changing the positioning of axles on which the balls rotate (diagram, right, shows cutaway Variator with hand regulating wheel).

"It's the Drive That's on the Ball."



WHAT'S NEW

stemming from cuts in the 1958 defense budget. Congress actually appropriated new obligational authority for the Defense Department that totals about $34.6 billion, (slightly less than 1957's $34.698 billion) divided as follows:

OSD	$16,350,000
Intr Srv Act	682,375,000
Army	7,264,550,000
Navy	9,866,355,000
Air Force	15,930,220,000
	33,759,850,000*

*Plus $590 million transferred from stock and industrial funds.

In the Navy's appropriation, about $1.9 billion will go into aircraft and missiles; $1.7 billion for aircraft and related components, $237 million for missiles, drones and related equipment. Before the appropriation bill was passed, the Navy planned to procure 1,220 aircraft with 1958 funds; now the Navy figures it will be able to buy only 1,025 (compared to 1,412 in the fiscal 1957 program).*

The Air Force received $5.9 billion in appropriations for aircraft and related procurement, $300 million less than requested. Originally, it had planned to procure 1,515 aircraft in fiscal 1958 and use $1.4 billion for missiles. There's been no decision as to where cuts will take place to effect the $300 million reduction.

The Army will use some of its procurement money for aircraft and guided missiles: $129 million for aircraft and $527 million for missiles.

• **Cutting down**—But what concerns business men more than the reduction in new obligational authority is Defense's plans to cut immediate expenditures. Last year's expenditures were planned to run $38.4 billion, and this year's were trimmed slightly to $38 billion. But somehow Defense Dept. spending got out of hand and threatened to run away. In the April-June quarter, spending jumped to an annual rate of $41 billion; and in the first quarter of 1958 edged up even higher to an annual rate of $42 billion.

Since both former Defense Secretary Charles E. Wilson and new Secretary Neil H. McElroy committed the department to maintain the $38 billion ceiling for fiscal '58, defense contractors are facing heavy cutting—for one quarter, spending will have to run at an annual rate of only $34 million, down $8 billion.

Another problem (due to be re-

** Figures were supplied by the Aircraft Industries Association of America, Inc.*

solved this month) that worries business men, is who is going to do what in the middle-range (1,500 mile) missile business. One of Wilson's last acts as Defense Secretary was to set up a committee to decide between the Army's Jupiter and the Air Force's Thor (probable decision: a combination using the best of each). Although the Army was restricted to work on missiles with maximum range of 200 miles by a previous directive, the 1,500-mile Jupiter has made several successful flights, while its Air Force competition has been unable to make one successful trip.

All this trimming has military contractors worried. Many of them are stepping up their attempts to get into civilian business (CtE, Aug. '57, p. 59) before the bulk of the cutbacks hurts.

GE Ships First Arizona-Built Computer

GE's first real entry into the computer field rolled off the partially completed production line at the company's newly established Computer Dept. in Phoenix in August. The device: a desk-size, transistorized analog computer, designed for office and factory use in production control work.

Unusual because it is an analog device doing a job usually assigned to a digital machine, GE's new computer can be used in any type of problem in which it is desired to multiply two numbers and then sum up the results. Typical examples:

- Analyze the effects of varying sales volumes and costs on profits.
- Show production bottlenecks to scheduling people in time for them to take corrective action. Machine will indicate a load impact of up to 50 different products as they affect up to 24 work stations.
- Calculate the effects on production of a new design or method which changes the amount of time or number of work stations required.

First units will be used by other GE divisions. However, the company expects to offer the unit for sale later this year. Expected selling price: $12,500 fob Phoenix.

Georgia Tech to Build Atlanta Reactor

Georgia Tech will get a $2.5 million gift from the state of Georgia to help build a research reactor, Gov. S. Marvin Griffin promised. The pledge was made as Dr. Walter H. Zinn described

(*Continued on page 156*)

Only with the KIN TEL DC amplifier!

You benefit by 500, years'

experience in critical applications

Input

strain, torque, flow, temperature, vibration, pressure, noise, displacement and other physical phenomena

Output

strip recorders, wideband oscilloscopes, voltage-controlled oscillators, recording galvanometers, tape recorders, analog-to-digital converters, computers, process control elements

It's the basic component for all data transmission

...and no other DC amplifier delivers *all* these specifications to you...now!

CHECK THESE OUTSTANDING FEATURES:
±2 microvolt stability...less than 5 microvolt noise ...±35V, ±40 ma output...high input impedance... low output impedance...10 accurate, continuously-variable gain ranges...6-unit rack mounting... integral power supply.
The KIN TEL "drift-free," wideband DC amplifier provides simple, accurate measurement of dynamic physical phenomena. It is a proven component for testing missiles, aircraft, buildings, bridges, ships, guns, heavy machinery...for medical research...for evaluating strength and riding quality of vehicles... for control of atomic reactors, and of chemical and industrial processes.

PROVEN RELIABILITY. Yes, KIN TEL DC amplifiers have more than 500 years' cumulative operating time. In one installation alone, they have logged an amazing record of over a million hours of stable, trouble-free operation. This kind of record is the result of stringent quality controls in every stage of manufacture ...of thorough testing and calibration prior to delivery...and of years of experience gained in the design and manufacture of thousands of chopper-stabilized DC amplifiers.

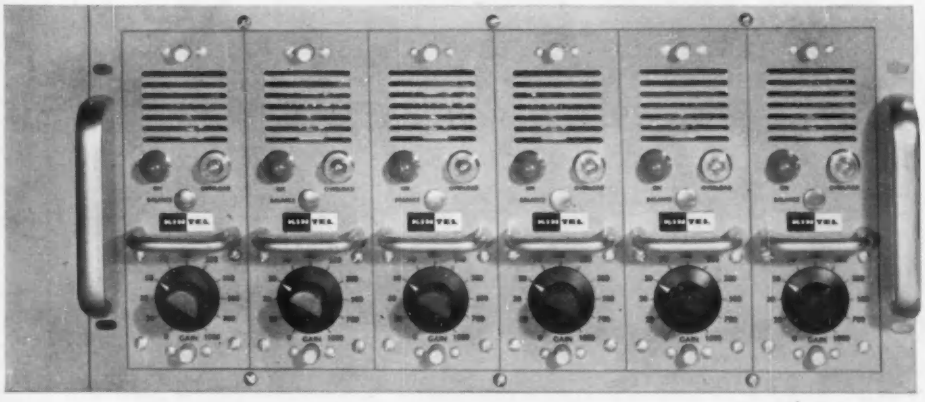
AMPLIFY MICROVOLTS WITH STABILITY. KIN TEL 111 series DC amplifiers provide unsurpassed dynamic performance, maximum stability and the lowest drift of any commercially available wideband DC amplifiers. They incorporate KIN TEL's proven chopper-amplifier circuitry and provide ten extremely precise, feedback-controlled gain ranges, plus continuously-variable gain adjustment between normal gain settings. Several feedback loops assure high accuracy, stability and uniform frequency response, unaffected by load or gain changes.

REPLACE COMPLEX, OBSOLETE CARRIER SYSTEMS. Existing carrier systems can be replaced by a KIN TEL packaged "plug-in" DC instrumentation system. These systems are complete from input transducer to output device. They provide greater accuracy and bandwidth, operational simplicity, and eliminate the capacitive balance problems of carrier systems.

WIDE CHOICE OF MODELS. The operational version of the KIN TEL DC amplifier permits the user to employ his own external feedback networks to provide up to 100% resistive or capacitive feedback around the amplifier...to obtain many desired amplifier characteristics, such as specific gains, integration, active filters, bandwidth limitations, and the generation of complex linear transfer functions. Floating input models eliminate the problem of ground loops, and are especially useful for grounded thermocouple measurements.

NATIONWIDE ENGINEERING STAFF. There are KIN TEL representatives in every major city. An experienced application engineer is always available to assist in solving your needs, and to prepare a detailed proposal.

FAST DELIVERY. KIN TEL offers immediate delivery from stock on reasonable quantities of standard amplifiers. Call the KIN TEL representative nearest you for information, or write us direct.



Six standard amplifiers in compact 19-inch rack mountable module – ideal for multiple channel installations.

model 111BF DC Amplifier

Gain (Phase Inverting)...Steps of 0, 20, 30, 50, 70, 100, 200, 300, 500, 700, 1000 with continuous variation between steps by potentiometer.
Gain Accuracy....±1%, DC to 2 KC; 3 db down at 40 KC.
Input Impedance.....100,000 ohms.
Output Impedance....Less than 1 ohm in series with 25 μh.
Equivalent Input Drift.....±2 μv.
Equivalent Input Noise....0 to 3 cps, less than 5 μv peak to peak. 0 to 750 cps, less than 5 μv RMS. 0 to 50 kc, less than 12 μv RMS.
Chopper Intermodulation.....Less than 0.1%.
Maximum Output Cable Capacity.....1.0 μf (external).
Linearity.....Better than 0.1% to 2 KC.
Output Capability.....0 to 35V where Rl> 1000 ohms. 0 to ±40 MA where Rl is 10 to 400 ohms.
Frequency Response....0.3 db (±3%) DC to 10 KC, less than 3 db down at 40 KC.
Rise Time.....Less than 10 μ sec.
Phase Shift.....Less than 5° to 2 KC.
Overload Recovery Time.....Less than 3 sec.
Dimensions:
Amplifier Unit.....2⅞" wide, 7⅝" high, 14⅝" deep.
Unit in Cabinet.....5-7/16" wide, 10" high, 18¼" deep.
Rack Adaptor Module for 6 Amplifiers.....19" wide, 8¾" high, 18¼" deep.
Power Requirements:
Amplifier.....117V (105-125V), 60 cycles, 70 VA.
Cabinet.....117V, 60 cycles, 15 VA.
6-Unit Module.....117V, 60 cycles, 45 VA.
Net Weight (Amplifier).....11 pounds.
Price: Amplifier.....$575.00*
Cabinet, with fan and connector.....$105.00
6-Unit Module, with fans and connectors....$200.00

Amplifier must be operated in Module or Cabinet

5725 Kearny Villa Road
San Diego 12, Calif.
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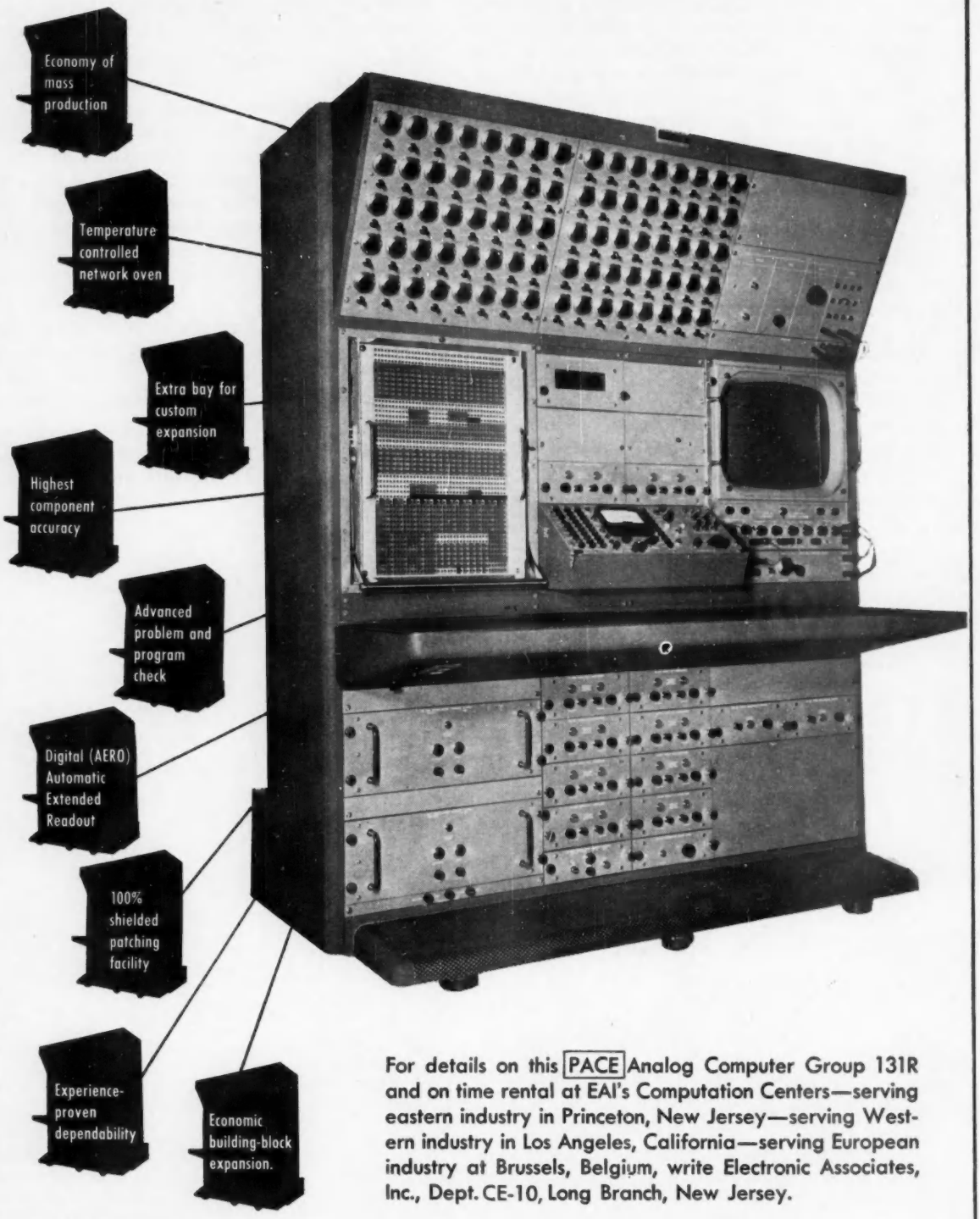

For details on this PACE Analog Computer Group 131R and on time rental at EAI's Computation Centers—serving eastern industry in Princeton, New Jersey—serving Western industry in Los Angeles, California—serving European industry at Brussels, Belgium, write Electronic Associates, Inc., Dept. CE-10, Long Branch, New Jersey.

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EAI SETS THE P PRECISION A ANALOG C COMPUTING E EQUIPMENT ®

LONG BRANCH • NEW JERSEY

Labor's New Assault— The Four-Day Week

When the United Automobile Workers (UAW-CIO) launch their 1958 assault on the auto companies in Detroit next spring, the four-day week is sure to be one of the top objectives. Union president Walter Reuther claims "the shorter week is the workingman's counterpunch against enforced leisure that will be the inevitable result of increased productivity stemming from the use of automatic controls."

Labor's counterpunch

Reuther championed the short week at UAW's constitutional convention in April; he won for it a place high on the list of demands prepared by delegates. Now he's laying the groundwork for its adoption next January by the membership. Only chance of an upset would come from a rarely undisciplined meeting placing greater immediate stress on pensions.

UAW likes to feel it is the bellwether of unions. Its politically ambitious president is determined that the auto workers lead the field. They were first with a guaranteed annual wage; he wants them to be first with the four-day week. And if the auto workers win it, steel, chemical, and electrical unions will be at the bargaining table next.

The "fight for leisure", as the union likes to call it, should rate more inches in the future's history texts than even Henry Ford's "five dollar day". Of course the idea of less work for the same pay is highly attractive to the men at the time-clock level. UAW's top echelon say they would oppose it as economically unsound if it threatened existing productivity. But they feel they need something to serve as a check against the inroads of automatic machines.

Fight for leisure

Widespread use of automatic controls is acknowledged as being inevitable by UAW-CIO planners. Officially they have never condoned a strike against a new machine. Their sharpest actions stem from the immediate problem of relatively small groups of workers displaced by individual installations of automatic machinery.

UAW spokesmen point to the stormy last years in Detroit of the Murray Corp. as a typical example. A subcontractor for Ford Motor Co., Murray employed 5,000 men in turning out about one-third of Ford Div.'s body stampings. When Ford mechanized its stamping activities, the increase in production was sufficient (it was tripled) to permit it to cancel the Murray contract. Murray had to lay off 5,000 of its work force.

CHOPPER APPLICATIONS

Servo Comparator

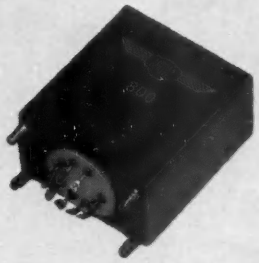
Where the difference between two voltages is required, a mechanical chopper develops such a signal. With a BBM chopper, the two voltage sources are isolated from each other. The error signal is modulated, the phase showing which voltage is the greater.

Type 313 for operation from −65 C to +125 C with NO derating

DC Amplifier

The mechanical chopper, because it has long-term stability, especially under fluctuating ambients, provides a simple and dependable means for modulating and demodulating DC signals for amplification in either vacuum-tube or transistor amplifiers.

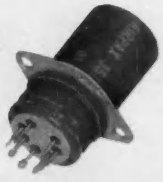
Type 176 drive coil leads out top for minimum noise



Operational Amplifier

Wide-band DC signals, such as in analog computers and proportional controls, are readily amplified in a directly coupled vacuum-tube or transistor amplifier whose zero is stabilized by a mechanical modulator.

Type 800 double-pole double-throw for full isolation



Guidance System

For guided missiles and other equipments subject to shock and vibration, the balanced-armature chopper is used. This chopper has the electrical stability of other mechanical modulators, plus unusual resistance to external disturbances.

Type 351 operates normally during 15 G vibration at 10 to 2500 CPS

Analog-to-Digital Converter

In such applications as production test equipment where digital indications are desirable, a mechanical chopper samples the analog input. The equipment retains its calibration, there being no drift in the chopper.

Type 175 standard plug-in 60-CPS unit

DC VTVM

Because of its stability, the mechanical modulator is used in vacuum-tube voltmeters. In such applications the chopper extends the DC sensitivity into the microvolt region, an order of magnitude beyond that usually possible.

Type 300 standard miniature 400-CPS SPDT unit

DESIGNERS AIRPAX ENGINEERS

AIRPAX PRODUCTS CO., CAMBRIDGE DIVISION, JACKTOWN ROAD, CAMBRIDGE, MARYLAND

Vertical integration's a culprit

This case illustrates Reuther's chief concern with automatic machinery: "vertical integration". If major auto makers find it cheaper to install automatic machinery and produce their own parts, he feels there's bound to be some violent dislocations for workers. And a substantial fringe will suffer permanent economic loss because of age or lack of skills required by the new machines. The union says these people need some kind of special attention.

One of the big question marks is just how the four-day week will make its first appearance in industry. The mathematics are obscure even to UAW planners. There's one opinion that thinks it will start as a demand for time-and-a-half for the fifth day, switching it into a simple pay raise.

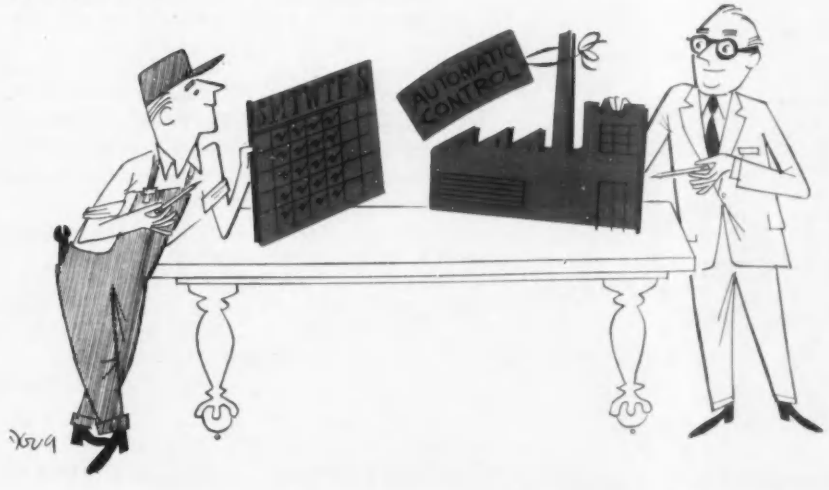
More support

But regardless of how it is worked out, the pressure for the short week is building up. More and more union people, such as Stanley Ruttenberg, director of research for the AFL-CIO, see the four-day week as a necessity. Ruttenberg explains it with figures. He says there are some 750,000 new people coming into the labor force every year at a time when new, more efficient equipment with automatic control systems are being introduced as well; something has to be done to give the worker a chance to be productive while giving the new machinery a chance to perform its technical improvements.

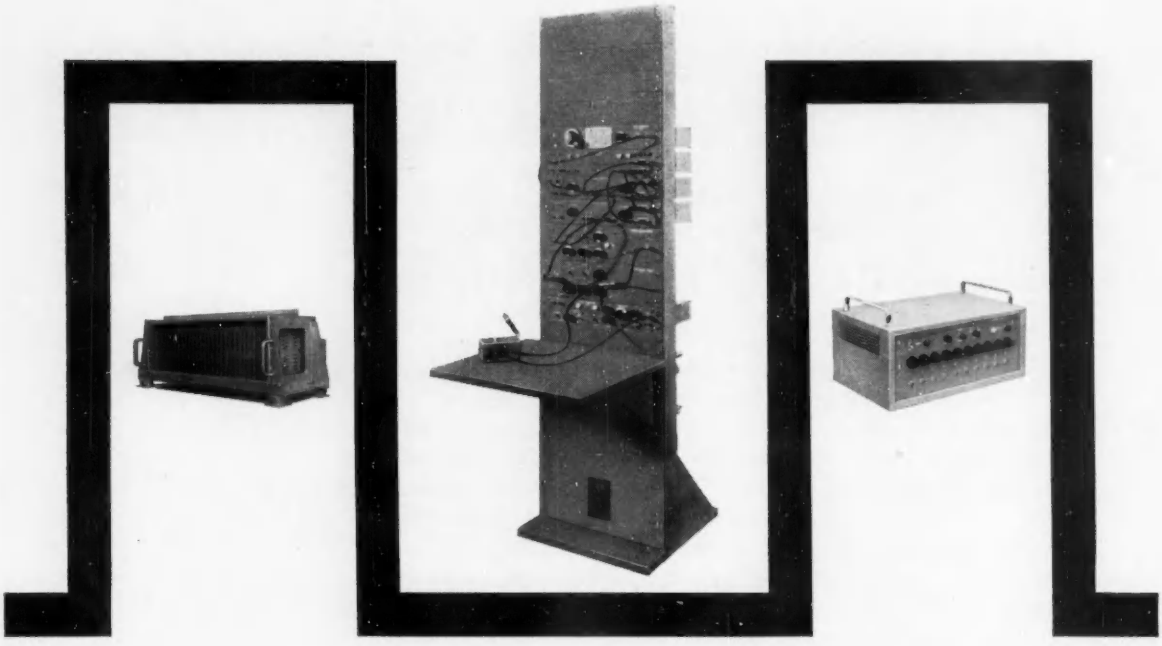
Oil will follow

Labor leaders feel that automatic controls will make its biggest impact in steel and the automotive industry. Industries like chemical and oil refining have little influence (despite a widespread use of automatic controls) because there are already so few workers, relatively, in jobs that make for unionism. Therefore, the oil and chemical workers will follow what the large manufacturing unions seek and get.

Union economists argue that the worker, on a four-day week, will eat as well or better, drive a better car over better highways and require more services that will pay off in purchases of goods that other people and machines make. The four-day week, they say, is giving the workers "their share" of technological advancements in the form of more leisure.



tools for digital techniques in the laboratory



tools for engineers

It wasn't long ago that the average digital specialist was spending more time breadboarding than he was solving problems. Long on ideas, he was woefully short on tools. That's why Burroughs organized the Electronic Instruments Division—*to supply the digital specialist with the laboratory test equipment his technology demands.* And it has!

Today E.I.D. offers the laboratory working in digital techniques specialized equipment and services in these three major areas:

(1) *Logical Building blocks.* Unitized Pulse Control Equipment that brings block diagrams to life in minutes for the solution of logical problems . . . permits fast test set-ups for testing components, circuits, systems. Plus the BCT-301, a complete system for putting magnetic cores in a simulated system and observing their performance.

(2) *Special purpose laboratory test equipment.* A group of instruments implementing the use of precision digital methods in comparison, measurement, and counting. Typical units are a precision delay generator . . . high frequency pulse generator . . . a device for displaying up to ten separate inputs on a scope face simultaneously . . . and a calibrator especially designed for measuring peak amplitude in millivolts.

(3) *Complete systems design.* When design and test requirements are extremely complex, E.I.D. will design, develop, and install a complete system . . . such as complete core memories, memory plane testers, digital computer subsections.

If you'd like to learn more about any particular area of E.I.D. service, we'll be happy to send you all the information available. You need only request it. But if you have a particular problem, why not send it along to us now. We'll gladly work with you in developing a solution. There's no obligation.

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Control
ENGINEERING
OCTOBER 1957

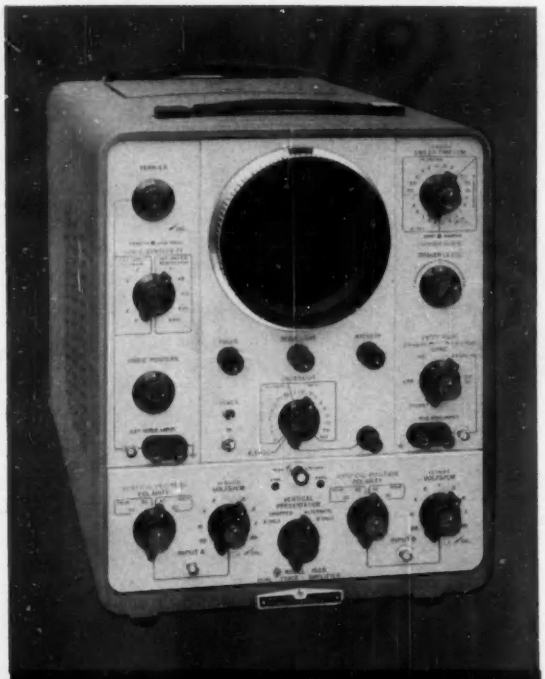
There's Still a Need

There are clear signs that the shortage of engineers is temporarily easing. A book just published by the National Bureau of Economic Research even asserts that "there is no evidence of a shortage of engineers". But don't push the panic button; we can't see a glut of engineers occuring in the control field for the next three years. American industry must have competent control engineers to design installations of the control equipment which we expect industry will purchase between now and the end of 1960 — at an increasing rate that will mean a 40 percent gain. Any hastily- or ill-conceived predictions of an oversupply of engineers in our field may jeopardize your ability to carry that increase. We urge you to continue to steer engineering students into this field. Sharpen your own knowledge of the principles and equipment used because we can see tougher sledding ahead for technical people who are not adequately trained and experienced in measurement and control.

Demand and Supply of Scientific Personnel is the title of the book mentioned in the preceding paragraph; D. M. Blank and G. J. Stigler are its authors. Apparently the only thing wrong with the conclusions of the authors is that they have used data which are four years out of date. The authors rely on the premise that engineer shortage is directly proportional to a ratio — increase in engineering salaries divided by increase in salaries of other workers. Using their data they calculated a ratio whose value was smaller than one. Therefore, they conclude, there is no shortage of engineers. However, let's use data that have a shorter response time, for example, the EJC Salary Survey covering 1956 and 1953. It shows that the average salary increase for members of EJC constituent societies from 1953 to 1956 was 25 percent. Meanwhile, the pay of all wage and salary employees increased only 12 percent. When you grind these figures through the Blank-Stigler formula the ratio is greater than one. According to this more timely analysis, a shortage does exist.

Is there any added comfort in industry's report, through the latest McGraw-Hill Dept. of Economics survey of plans for capital investment, that it expects to employ 15 percent more scientists and engineers in development work in 1960 than in 1957? There is, if all you want is assurance. We suggest you take a clearer lesson from the experience of engineers discharged a few weeks ago in southern California and on Long Island because of cutbacks in defense contracts. They readily found new work (frequently in the Mid-West) if they were well-trained and technically competent. This is your insurance at a time when the gap between supply and demand has narrowed — technical training and competence.

THE EDITORS



-hp- 150A

HIGH FREQUENCY OSCILLOSCOPE

New reliability • New convenience
DC to 10 MC. Plug-in preamplifiers
24 direct reading sweep times
Sweeps 0.02 μsec/cm to 15 sec/cm
"Universal" automatic triggering
New, ultra-conservative design

SPECIFICATIONS

Sweep Range: 0.02 μsec/cm to 15 sec/cm.

Calibration: 24 sweeps: 1-2-5-10 sequence, 0.1 μsec/cm to 5 sec/cm. 3% accuracy.

Triggering: Internal, line voltage or external 0.5 v or more. Pos. or neg. slope, +30 to −30 v trigger range.

Preset Trigger: Optimum setting for automatic stable triggering.

Horizontal Amplifier: Sweep magnification 5, 10, 50, 100 times. Vernier position control selects any 10 cm part of sweep. External input pass band dc to over 500 KC. Sensitivity 200 mv/cm to 15 v/cm.

Vertical Amplifier: Pass band dc to 10 MC. Optimum transient response and rise time less than 0.035 μsec. Signal delay of 0.25 μsec permits leading edge of triggering signal to be viewed.

Amplitude Calibration: 18 calib. voltages, 1-2-5-10 sequence, 0.2 mv to 100 v peak-to-peak. Accuracy 3%. Approx. 1 KC square wave, rise and decay approx. 1.0 μsec.

Prices: -hp- 150A High Frequency Oscilloscope, $1,100.00
-hp- 151A High Gain Amplifier, $200.00
-hp- 152A Dual Channel Amplifier, $250.00

New Model 150A is not a "warmed-over" imitation of previous oscilloscopes. Instead it is a totally new kind of instrument whose radical design approach obsoletes old standards of oscilloscope versatility, simplicity and dependability.

Specifications given here spell out the 150A's unique usefulness. Its simplicity and reliability stem from such unique features as: ***Unitized circuits,*** easily isolated for testing or service, etched and mounted on translucent plastic. ***Highest quality components,*** operated well below ratings. ***Concentric, color-coded,*** functionally-grouped controls. ***Direct sweep-time selection;*** no mental gymnastics. ***Universal automatic triggering*** system wherein one preset adjustment provides optimum triggering for almost all conditions.

Wouldn't you prefer a ***really new, convenient*** oscilloscope? Call your -hp- representative today for the complete story. Or, write direct.

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also offers -hp- 130A Low Frequency Oscilloscope, dc to 300 KC, sweeps 1 μsec/cm to 12.5 sec/cm.

Designing Stability into Hydraulic Governors

THE GIST: The hydraulic governor is a vital part of the speed-control loop in many pieces of large rotating equipment. In fact, the governor itself spans most of the loop, since it contains the feedback transducer (mechanical flyball), the amplifier (pilot valve) and the servomotor (hydraulic cylinder). The governor designer is dealing, therefore, with a full-fledged servomechanism and encounters the same incentives for dynamic analysis as do designers of the most extensive feedback control systems.

In this article the authors detail completely a proven method for the design and analysis of a hydraulic servomotor governor. The major feature of the method is that it does not involve the use of complex variables and Laplace transforms, which have become such dominant factors in most of today's servo work. Instead, the authors have chosen the classical methods of deriving and solving the differential equations needed to describe the dynamic operation of the governor. This approach is shown to be extremely effective for this application and to have the great benefit of being well adapted to the needs of mechanical engineers who are not familiar with the latest control system theories. Particularly intriguing is the logic that leads to the expression of the stability criterion as a single quantity.

E. Y. SOOMIL and V. G. GUINS
Westinghouse Electric Corp.

When used to drive electric generators, prime movers such as steam and hydraulic turbines are usually provided with governor valves or variable pitch nozzles. These open and close automatically to regulate the flow of working fluid in accordance with the load on the generator and thereby maintain an approximately constant speed of operation. While satisfactory for small turbines, direct-acting governors lack sufficient power to move the valves and nozzles of larger units. For this reason, some type of hydraulic actuator or "servomotor" is interposed between the speed-sensitive element and the control valve or nozzle.

Figure 1 reveals the construction details and the mode of operation of the pistons and linkages in a common type of hydraulic servomotor governor. Turbine shaft 1 drives speed-sensitive element 2, consisting of spring-counterbalanced weights that are shifted by centrifugal forces in proportion to turbine speed. A system of linkages transmits the movement of the weights to spool 3 of a hydraulic pilot valve or "relay" that controls the flow of oil to the servomotor cylinder. Piston 4 of this cylinder supplies the amplified forces needed to reposition valve 5 that adjusts the flow of steam to the turbine.

To follow the sequence of operation, assume that the load on the generator is lightened, resulting in a lesser demand on the turbine. Momentarily, the steam-power input to the turbine exceeds that needed to supply the mechanical power delivered at the output shaft, and the machine accelerates. With the increase in speed, the weights move out, lifting the spool of the hydraulic relay. This ports oil pressure to the blind end of the cylinder and opens the rod end to sump so that the piston follows the motion of the spool. The upward movement of the piston causes control valve 5 to close partly as needed to restore the balance between steam-power input and mechanical-power output. By the time that this balance again exists, the regulator

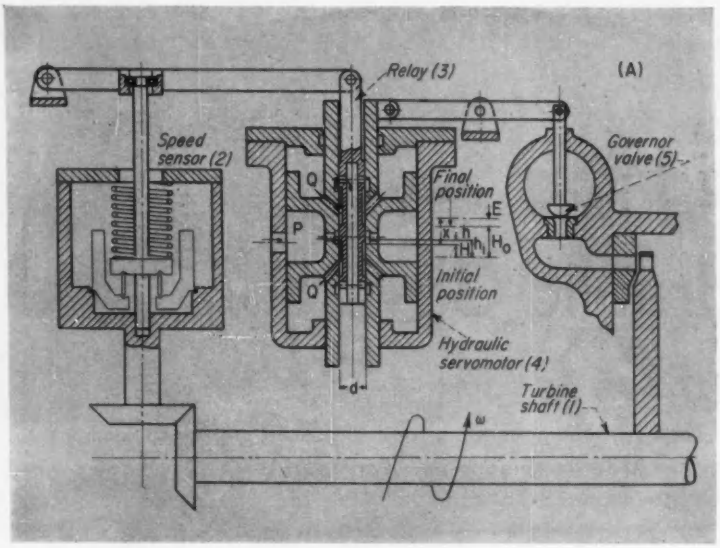


FIG. 1. Assembly view of a common type of hydraulic servomotor governor. In this case the flyball speed sensor actuates a hydraulic pilot valve, thereby controlling the movement of the servomotor piston.

valve, the piston, and the speed sensor weights have come to rest in their new positions, while the relay spool has returned to its neutral position.

Similarly, a decrease in speed is accompanied by downward movements of the relay spool and the piston, opening the control valve to admit more steam to the turbine.

It is obvious that the piston lags behind the relay in following it as it takes a certain relay port opening (h) to allow the oil to flow. For an infinitesimally slow change in load the movements of the relay and piston will also be infinitesimally slow, requiring an infinitesimally small flow and port opening. A very small relay and speed-sensitive element would be adequate. This may not be so for a sudden change in load which imposes the most severe demand on the operation of the governor. Therefore, a mathematical analysis of such operation will be made in order to furnish a basis for the selection of the relay size and the speed-sensitive element size.

The basic behavior of the governor at sudden change of load can be reasoned out without recourse to mathematics. At the first moment, when the difference between input and output is the greatest, the machine acceleration, port opening, and piston speed are at maximum. As the governor valves approach the position needed to accommodate the new load, all the above listed variables decrease toward zero. When the piston and governor valve reach the final position, the opening of the relay ports will be approximately zero and the machine speed will be near its steady-state value.

DYNAMIC ANALYSIS

The first major step in the mathematical analysis is to develop the equations describing the dynamics of governor operation. The constants and variables affecting this operation are listed in the accompanying table of symbols. In the sections that follow equations will be written showing the relationships among all of the variables.

Excess torque (T) and piston travel (H_o)

If the load suddenly decreases by the amount of ΔW (expressed in kilowatts), input torque momentarily will exceed output torque. The magnitude of excess torque in lb-in. is

$$T_1 = \frac{\Delta W \times 85{,}000}{N}$$

As piston 4 (Figure 1) moves to close the governor valve, the excess torque decreases. This decrease is directly proportional to piston travel because the torque varies linearly with the steam flow (from the well-known Willans line), and because the variation of steam flow with piston travel is approximately linear. The excess torque becomes zero when the piston has traveled the distance H_o and reached its final position. If H is the piston travel from the initial position and $x = H_o - H$, then the excess torque at any given point in the piston stroke is given by:

$$T = \frac{\Delta W \times 85{,}000}{N} \times \frac{x}{H_o}$$

As the load decreases, the speed increases. The exhaust flow then exceeds the inlet flow, leading to a drop in pressure and allowing the steam inside the turbine to expand. To take this secondary effect into account, the factor K_6 is introduced. This constant is defined as the ratio of energy content of the steam inside the turbine downstream of the governor valve to the increase in kinetic energy of the rotor from initial to final speed. (Note that K_6 is zero for incompressible fluids). The final expression for excess torque then becomes:

$$T = \frac{(1 + K_6)\,\Delta W \times 85{,}000}{N \times H_o} \qquad (1)$$

Torque and acceleration

The angular acceleration of the turbine rotor due to the excess torque is: $\frac{d\omega}{dt} = \frac{Tg}{I}$ (2)

Piston travel (x) and oil flow (Q)

Because the piston displacement is equal to the volume of oil admitted, the following may be written:

$$-A\,dx = Q\,dt \tag{3}$$

Oil flow (Q) and port opening (h)

Let P = oil supply pressure

$\frac{F}{A}$ = differential pressure on operating piston

$\left(P \pm \frac{F}{A}\right)$ = pressure drop through pilot valve. One-half of this is pressure drop through each port opening. The plus is used for closing and the minus sign for opening the steam valves.

$\pi\,dh$ = area of port opening

Then, the oil flow is given by:

$$Q = 40C_d\pi\,dh\sqrt{\tfrac{1}{2}\left(P \pm \frac{F}{A}\right)}\ \text{gpm} \tag{4a}$$

$$Q = 154C_d\pi\,dh\sqrt{\tfrac{1}{2}\left(P \pm \frac{F}{A}\right)}\ \text{cu in./sec} \tag{4}$$

Speed (w), port opening (h) and piston travel (x)

As the machine accelerates from ω_1 to ω, the centrifugal force F_1 exerted by the weights is proportional to the increase in speed, or:

$$F_1 = K_2(\omega_1 - \omega)$$

This force has to overcome the force F_2 of the spring and the hydrodynamic force F_d of the relay valve. Thus: $F_1 = F_2 + F_d$ (5a)

The force of the spring is proportional to the pilot travel, which is the sum of the piston movement and port opening: $F_2 = K_1(h + H) = K_1(h + H_o - x)$

The hydrodynamic force of the pilot valve arises from the reaction of the stream of oil discharged through the port. According to the momentum theorem, this force is proportional to the product of the mass flow and the velocity of the stream, or:

$$F_d = K_7\frac{QV\gamma}{g}$$

Now V can be obtained by inspection from Equation 4: $V = \sqrt{\tfrac{1}{2}\left(P \pm \frac{F}{A}\right)}$ (5b)

Therefore, from Equations 4 and 5:

$$F_d = K_7\frac{(154)^2}{g}C_d\pi\,dh \times \tfrac{1}{2}\left(P \pm \frac{F}{A}\right)\gamma$$

Experimentally it was found that:

$$\tfrac{1}{2}K_7\frac{(154)^2}{g}C_d\pi\gamma = 2.7$$

Hence, $F_d = 2.7d\left(P \pm \frac{F}{A}\right)h$ (5c)

For a given relay valve diameter d, oil pressure P and force F: $F_d = K_3h$ where

$$K_3 = 2.7d\left(P \pm \frac{F}{A}\right) \tag{5d}$$

By substitution, Equation 5a becomes:

$$K_2(\omega - \omega_1) = K_1(h + H_o - x) + K_3h$$
$$= (K_1 + K_3)h - K_1x + K_1H_o$$

For the final conditions of $h = 0$, $\omega = \omega_2$, and $x = 0$: $K_2(\omega_2 - \omega_1) = K_1H_o$

$$K_2 = \frac{K_1H_o}{\omega_2 - \omega_1}$$

Then $K_1H_o\frac{\omega - \omega_1}{\omega_2 - \omega_1} = (K_1 + K_3)h - K_1x + K_1H_o$

Now, let $K_5 = \frac{K_3}{K_1}$

Then $H_o\frac{\omega - \omega_1}{\omega_2 - \omega_1} = (1 + K_5)h - x + H_o$

and differentiating:

$$\frac{H_o}{\omega_2 - \omega_1}d\omega = (1 + K_5)\,dh - dx \tag{5}$$

STABILITY CRITERIA

The group of equations numbered 1 through 5 above include the following six variables: angular speed of the rotor (ω); time (t); excess torque (T); piston position (x); oil flow (Q); and port opening

TABLE OF SYMBOLS

Variables

ω = angular speed of the rotor, rad/sec
t = time, sec
T = excess torque, lb-in.
H = piston travel from initial position, in.
Q = oil flow, cu in./sec
h = port opening, in.
$x = H_o - H$

Constants

I = moment of inertia of the rotor, lb-in^2.
g = acceleration of gravity, in./sec^2
ΔW = output change, kw
H_o = total piston travel between initial and final position, in.
N = speed, rpm
A = net area of piston, sq in.
C_d = pilot valve discharge coefficient
d = pilot valve diameter, in.
P = governor oil pressure, psi
F = force exerted by piston on regulator valve, lb
F_o = initial force of governor spring (referred to pilot valve), lb
K_1 = governor spring modulus (referred to pilot valve), lb/in.
K_2 = centrifugal force change referred to pilot valve per radian/sec change in speed, lb-sec/radian
ω_1 = initial angular speed of the rotor, rad/sec
ω_2 = final angular speed of the rotor, rad/sec
K = 154 (dimensional constant to give Q in cu in./sec)
K_3 = hydrodynamic force factor, lb/in.
$K_5 = \frac{K_3}{K_1}$ (hydrodynamic force coefficient)
B = behavior coefficient
K_6 = expansion factor
$R = \frac{\omega_2 - \omega_1}{\omega_1}$ (regulation)
γ = oil density, lb/in.^{3}
$D = B(1 + K_5)$ = dynamic coefficient

(h). By substitution within the five equations, ω, t, T, and Q can be eliminated, yielding the following relationship between h and x:

$$(1 + K_s)\frac{dh}{dx} = 1 - B\frac{x}{h} \tag{6}$$

where

$$B = \frac{16{,}500\,(1 + K_s)\,\Delta WA^{-3/2}}{RN^2\frac{I}{g}C_d\pi^2 d\sqrt{\frac{1}{2}\left(P + \frac{F}{A}\right)}} \tag{7}$$

Before establishing the mathematical test for hydraulic servomotor stability, it is well to state in physical terms exactly what the criteria are. First, a governor is stable if the relay ports close fully $(h = 0)$ when the piston reaches its final position $(x = 0)$. Second, when the piston comes to rest in this position, the machine speed must have reached its steady-state value.

Now, to translate these criteria into mathematical terms, examine Equation 6. This relationship between h and x forms the basis for examining any given design of hydraulic governor to determine if h and x actually do become zero simultaneously; i.e., to determine whether or not the design will yield inherent stability. Now, a new constant will be introduced. This constant is D, defined by:

$$D = B(1 + K_s)$$

This constant determines the variation of h with x, and can be used as the mathematical criterion of stability. It will now be shown that the stability requirements are fulfilled when D is less than 0.25. In the latter case, the solution of Equation 6 is:

$$\frac{x}{H_o} = \sqrt{D}\left(\frac{\frac{1}{2} + \sqrt{\frac{1}{4} - D}}{\frac{1}{2} - \sqrt{\frac{1}{4} - D}}\right)^{\frac{1}{4\sqrt{1/4 - D}}} \times \frac{[\frac{1}{2} - \sqrt{\frac{1}{4} - D} - (1 + K_s)u]^{\frac{1}{4\sqrt{1/4 - D}}-1/2}}{[\frac{1}{2} + \sqrt{\frac{1}{4} - D} - (1 + K_s)u]^{\frac{1}{4\sqrt{1/4 - D}}+1/2}} \tag{8}$$

where $u = \dfrac{h}{x}$

With Equation 8 available, the curves shown in Figure 2 can be drawn. The curve of u vs. x is tangent to horizontal line cb and passes through point a, whose coordinates are

$$u = 0; \quad x = H_o$$

and through point c, whose coordinates are

$$x = 0; \qquad u = \frac{\frac{1}{2} - \sqrt{\frac{1}{4} - D}}{1 + K_s}$$

The second curve in Figure 2 is that of h/H_o vs. x, which is found by reducing each u ordinate in the first curve by the ratio x/H_o. This second curve passes through points a and 0 and is tangent to the straight line ob.

The next step is the derivation of a curve, Figure 3, showing the relationship between port opening h and piston travel x. This is easily obtained from the graph of h/H_o vs. x described above. The ordinate of point b is known as the "critical port opening" and is defined as:

$$h_{cr} = \frac{\frac{1}{2} - \sqrt{\frac{1}{4} - D}}{1 + K_s} \times H_o \tag{9}$$

It is apparent from Figure 4 that there is close agreement between the curve of h vs. x calculated by this method and a curve of the same relationship as determined experimentally. The experimental curve was obtained by means of an instrument of the kind used for making indicator diagrams of reciprocating engines. As depicted in Figure 5, the indicator was mounted on the operating piston, the tracing point connected to the pilot valve, and the end of the string rotating the cylinder attached to a stationary point.

The curve of the angular speed of the rotor (ω) vs. piston position (x) is obtained from Equation 5f, which can be rewritten as:

$$\omega = \omega_1 + \frac{H_o - x}{H_o}(\omega_2 - \omega_1) + \frac{(1 + K_s)h}{H_o}(\omega_2 - \omega_1) \tag{10}$$

Note that the first and second terms on the right represent the steady-state speed which would be maintained during a slow change in load. The remaining terms furnish a measure of how much the speed departs from the ideal during a sudden change in load. Figure 6 gives the curves of ω vs. x for both types of load changes. Actually, the horizontal axis of Figure 6 is in terms of percent of load, the values for which are obtained by applying a suitable conversion factor to x. These curves are derived under a procedure similar to that used previously for the curve of h vs. x, except that the critical port opening h_{cr} is replaced by the critical speed difference or:

FIG. 2. First step in a graphical analysis of the dynamic operation of the servomotor governor is derivation of curves of u and h/H_o vs. x.

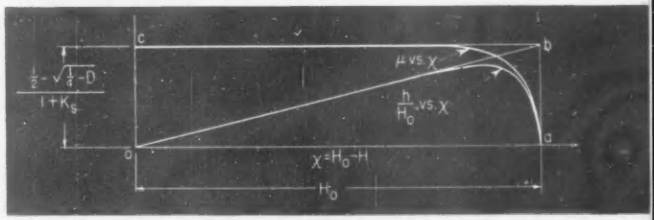
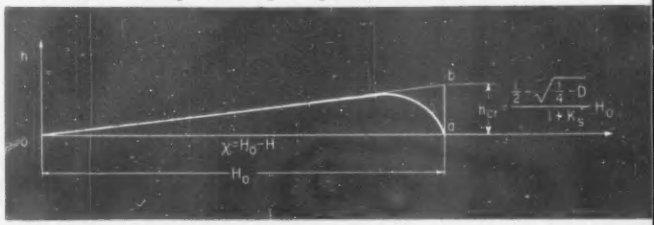


FIG. 3. Relationship between port opening h and piston travel x.



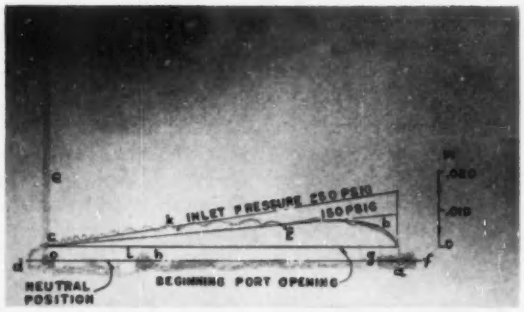


FIG. 4. Indicator diagram superimposed on derived curve shows close correlation between test and calculated data.

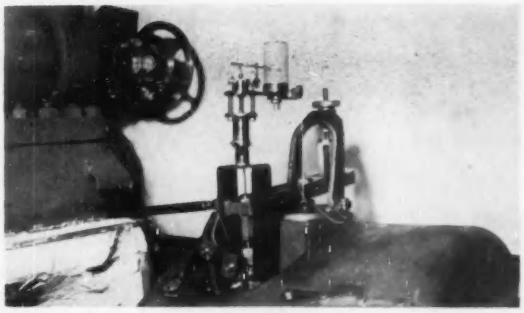


FIG. 5. Arrangement of test apparatus for obtaining indicator diagram of servomotor performance.

$$\Delta\omega_{cr} = \frac{(1+K_s)h_{cr}}{H_o}(\omega_2 - \omega_1)$$

$$= (\omega_2 - \omega_1)(\tfrac{1}{2} - \sqrt{(\tfrac{1}{4} - D)} \qquad (11)$$

It can be seen from Figures 3 and 6 that when the piston reaches its final position, the port opening is zero and the speed is the steady-state speed. Thus the stated requirements have been satisfied and the system is inherently stable.

While the above analysis is certainly valid for all values of D less than 0.25, it is also possible that the system will remain stable for greater values of D. However it can be seen from Equation 11 that for $D = \frac{1}{4}$, the critical speed difference is

$$\Delta\omega_{cr} = \tfrac{1}{2}(\omega_2 - \omega_1)$$

This is regarded as a maximum safe speed "jump" due to load changes, because with larger fluctuations the turbine speed might momentarily exceed the no-load value—a condition which should never be allowed to occur, because with no load on the turbine (other than losses) and even with the control valve closed, the speed will tend to remain the same, having overshot the steady-state, no-load value. Therefore, the dynamic analysis of conditions arising when D exceeds 0.25 would not be of great practical importance.

DESIGN PROCEDURE

Dynamic analysis has shown that the operation of the governor is stable when

$$D < 0.25$$

or

$$B(1 + K_s) < 0.25$$

By substituting from Equations 5d, 5e and 7, this criterion may be restated as follows:

$$\frac{16{,}500(1+K_s)\times\Delta W A\left[1+\dfrac{2.7d\left(P+\dfrac{F}{A}\right)}{K_1}\right]}{RN^2\dfrac{I}{g}\times C_d\pi^2 d\sqrt{\tfrac{1}{3}\left(P+\dfrac{F}{A}\right)}} < 0.25 \qquad (12)$$

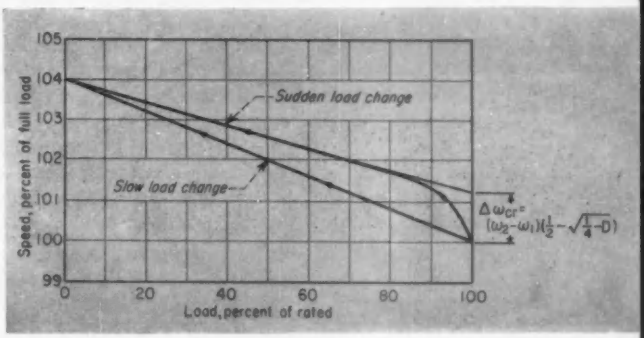


FIG. 6. Curves depict speed changes with both fast and slow shifts in load.

The quantities ΔW, K_s, R, N, $\frac{I}{g}$ and F are known for a given turbine.

Also, the value of discharge coefficient C_d can be assumed to be 0.50. The governor designer has the responsibility to determine or select governor oil pressure P; piston area A; pilot valve diameter d and spring modulus K_1. Since Equation 12 will give only one of these quantities if the other three are known, it will be reserved for the constant K_1. The quantities P, A and d will be determined by other means—the general objective being to obtain a minimum K_1 since a "soft" spring in the speed-sensitive element permits the use of small weights, lightens the load on the knife-edge bearings and lengthens service life.

Oil pressure (P) and piston area (A)

The force of oil, PA, on the piston must exceed the valve force F to enable the opening of the valve. This may be stated as:

$$PA = C_1F \quad \text{with} \quad C_{1\,cr} > 1$$

According to Equation 12, the area A should be as small as possible for a given oil pressure. Therefore, the constant C_1 should be made as small as possible. Yet, to provide a liberal margin for overcoming friction, C_1 should not be smaller than 2. Now, the

expression $A = C_1 F/P$ can be substituted in Equation 12 and D solved for as follows:

$$D = \frac{16{,}500(1 + K_6)\Delta W\left(\frac{C_1 F}{P} + \frac{2.7d(C_1 + 1)F}{K_1}\right)}{RN^2 \frac{I}{g} C_d \pi^2 d\sqrt{\tfrac{1}{2}\left(P + \frac{F}{A}\right)}} \qquad (14)$$

The last equation indicates that it is advantageous to use as high an oil pressure (P) as possible, provided the piston area (A) can be reduced to suit. In many control systems pressures up to 2,000 psi are employed. Now, in steam turbines both governor oil and lubricating oil are usually supplied from the same pump. Since lubricating oil is delivered to the bearings at about 10 psi, a pump discharge pressure of 2,000 psi would necessitate considerable pressure reduction with consequent wasteful energy dissipation. By way of compromise, therefore, 50 to 100 psi is the normal range of pump discharge pressures specified for turbine governors. Of course, if the value of the area is already fixed, Equation 15 shows that the pressure should be just high enough to satisfy Equation 13, with $2 < C_1 < 3$.

Pilot valve diameter (d)

Since diameter d appears both in the numerator and denominator in Equation 12, it has little effect on stability. This is so because regardless of whether the pilot-valve diameter is small or large, the flow required by Equation 4 can be achieved by providing more or less port opening (h). As long as the product $h \times d$ does not change, the flow and the hydrodynamic force remain the same despite shifts in either variable. One rule established by the dynamic analysis (Equation 9) is that h should never exceed the critical port opening (h_{cr}). Furthermore, to keep port area less than the annular area of the pilot valve recess, the relationship $h_{cr} < d/16$ should be observed.

Because the port opening is kept below h_{cr}, the limiting volume of oil flow may be found from Equation 4a, or:

$$Q_{max} = 40 C_d \pi d h_{cr} \sqrt{\tfrac{1}{2}P + \frac{F}{A}}) \text{ (gpm)} \qquad (15)$$

Therefore it is not necessary to provide an orifice in the oil supply line to protect the lube system from excessive demand of the governor.

NUMERICAL EXAMPLE

A design will be developed on the basis of actual quantities to illustrate the workings of this method. The parameters are as follows:

Output change, W = 2,400 kw (2,000 kw turbine-generator at 20 percent overload)

Valve force, F = 400 lb

Total piston travel, H_o = 0.5 in.

Expansion factor, K_6 = 0.1

Speed, N = 4,000 rpm

Regulation, R = 0.036

$\frac{I}{g}$ = 2,900 lb-in. sec²

Governor oil pressure, P = 55 psi

Relay discharge coefficient, C_d = 0.50

Using 3 as a liberal value for C_1, the piston area is found as follows:

$$A = \frac{C_1 F}{P} = \frac{3 \times 400 \text{ lb}}{55 \text{ lb/in.}^2} = 21.8 \text{ sq in.}$$

This area is provided by a 5.27-in. piston diameter.

$$P + \frac{F}{A} = 55 + \frac{400}{21.8} = 73 \text{ psi}$$

Since pilot valve diameter is not critical, a value of 1 in. can be tried for d. Also, assume a conservative value of 0.15 for D. Then, Equation 15 becomes:

$$0.15 = \frac{16{,}500 \times 1.1 \times 2{,}400 \times 21.8\left(1 + \frac{2.7 \times 1 \text{ in.} \times 73 \text{ lb/in.}^2}{K_1}\right)}{0.036 \times 4{,}000^2 \times 2{,}900 \times 0.50 \times \pi^2 \times 1 \times \sqrt{\tfrac{1}{2} \times 73}}$$

$$0.15 = 0.019\left(1 + \frac{197 \text{ lb/in.}}{K_1}\right)$$

Then the modulus for the spring of the speed-sensitive element is:

$$K_1 = \frac{197 \text{ lb/in.}}{\frac{0.15}{0.019} - 1} = \frac{197}{6.9} = 28.5 \text{ lb/in.}$$

Now, from Equation 5d:

$$K_3 = 2.7d\left(P + \frac{F}{A}\right) = 2.7 \times 1 \text{ in.} \times 73 \text{ lb/in.} = 197 \text{ lb/in.}$$

And, from Equation 5e:

$$K_5 = \frac{K_3}{K_1} = \frac{197 \text{ lb/in.}}{28.5 \text{ lb/in.}} = 6.9$$

From Equation 9:

$$h_{cr} = \frac{\frac{1}{2} - \sqrt{\frac{1}{4} - D}}{1 + K_5} H_o = \frac{\frac{1}{2} - \sqrt{0.25 - 0.15}}{1 + 6.9} \times 0.5 = 0.012 \text{ in.}$$

Since this h_{cr} of 0.012 in. is less than $d/16$ or 0.062 in., the value of 1 assumed for d is satisfactory. Lastly, from Equation 4A,

$$Q_{max} = 40 \times 0.50 \times \pi \times 1 \times 0.012\sqrt{\tfrac{1}{2} \times 73} = 4.6 \text{ gpm}$$

Triggering Electronic Flip-Flops from Mechanical Switches

A new transistor circuit at last makes mechanical-switch inputs compatible with sensitive flip-flops. The circuit converts multi-peak ("hashy") wave forms into a single pulse that prevents random triggering. Features of the transistor converter are 1-microsec rise-time and a reset characteristic adjustable to the switching cycle.

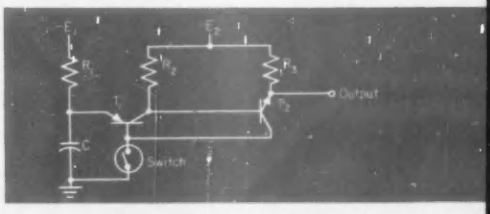


FIG. 1. Schematic diagram of two-transistor pulse generator.

ROLAND YII, Burroughs Corp.

Reliable operation of a sensitive electronic flip-flop calls for input pulses that are clean and sharply defined. This requirement means that by itself the mechanical switch is not a satisfactory source of triggering signals for high-speed counters and registers. The arcing and bounce encountered in the contact operation of devices such as pushbuttons, relays and telephone dials produce random triggering and multiple transfer of a flip-flop even when a single count is desired.

A novel two-transistor circuit has been developed to "clean" the pulses formed by switch contacts and to transform an erratic input signal into a single fast-rising, high-peak output pulse. With the circuit, the effects of arcing and bounce are suppressed and random triggering is eliminated. Hence, this development makes it practical now to use mechanical switching for the control of a flip-flop.

Circuit operation

A schematic diagram of the filter circuit is shown in Figure 1. The two transistors are of different types: T_1 is *pnp* and T_2 is *npn*. The input switch contacts are in the base circuit of transistor T_1 while the output pulse appears at the emitter of T_2. The rise time of the output pulse is limited only by the inherent switching time (from cut-off to saturation) of the transistors selected. It can be as short as 1 microsec or less.

The operating voltages are chosen so that the magnitude of E_2 is much greater than that of E_1. Another design condition is that R_1 be made considerably larger than the ratio $R_2R_3/R_2 + R_3$. The circuit depicted in Figure 1 produces a positive-going pulse. Reversing the polarity of the power supply and interchanging the transistors so that the *npn* unit is at the left yields a negative-going output pulse.

When the switch is closed, transistor T_1 is cut off because its emitter is biased at a lower (more negative) voltage than the base.

For a *pnp* transistor to conduct, its emitter must be positive with respect to the base. Hence, when the switch is closed, transistor T_1 is cut off because its emitter is biased at a lower (more negative) voltage than is the base. Emitter and base voltages of *npn* transistor T_2 are approximately equal so that this unit, which is working as an emitter follower, is also near cut-off. Conduction in T_2 is possible only when its emitter is more negative than its base.

The first objective in the study of this circuit is to learn how a sharp output pulse is generated by the opening of the switch contacts. The second is to see how the circuit accepts only the initial input signal and rejects spurious additional pulses.

Opening the switch frees the base of T_1 and the collector of T_2 from ground. Now the electrical charges stored as a result of the internal capacitance of the transistors are released so that the base voltage of T_1 tends to follow its collector voltage. The rate at which the base voltage of T_1 drops (becomes more negative) depends on the magnitude of the collector resistance and capacitance. Part of the latter is inherent in the type of transistor selected and some is the stray wiring capacitance between the collectors and bases. The time constant is given as

$$t_b = \left(C_{c1} + C_{c2} + C_{stray}\right) \frac{r_{c1}\, r_{c2}}{r_{c1} + r_{c2}}$$

where

C_{c1} = Collector junction capacitance of transistor T_1
C_{c2} = Collector junction capacitance of transistor T_2
C_{stray} = stray wiring capacitance
r_{c1} = resistance between collector and base of transistor T_1
r_{c2} = resistance between collector and base of transistor T_2

The delay between the opening of the mechanical

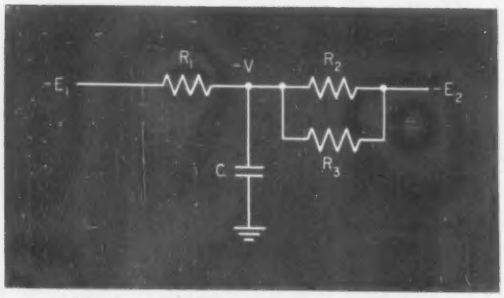


FIG. 2. Equivalent circuit of pulse generator when both transistors are saturated.

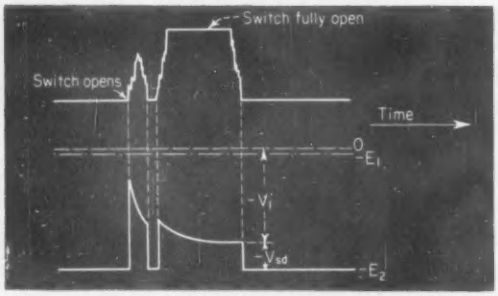


FIG. 3. Waveform (top) shows erratic pulses formed on a single operation of switch contacts; lower trace shows fast-rising first pulse and suppressed second pulse produced by transistor circuit.

switch and the initiation of the output pulse is determined by both this time constant and the emitter bias $-E_1$. As long as T_1 remains cut off while the base voltage is dropping, there is no output pulse. However, as soon as the base voltage approaches that of its emitter, transistor T_1 starts conducting. Now the collector voltage rises with the increasing collector current. T_1 reaches saturation after the base voltage has fallen far enough.

When T_1 is in the active region, T_2 is in this region also because its emitter junction is biased in the forward direction, its collector junction in the reverse direction. Therefore, the emitter voltage of T_2 follows its base voltage. Note that in this circuit the collector of each transistor is connected to the base of the other. Hence, transistors T_1 and T_2 become saturated at the same time, when collector and emitter junctions are biased in the forward direction.

The wave form of the output is always the same as that observed at the collector of T_1 because of the parallel action of the two transistors. The rise time of the output pulse is determined by the switching time of T_1, which is the period taken to reach conduction saturation. If the stray capacitance of the wiring is kept low, the switching time depends only on the internal characteristics of the individual transistors. Rise time is a few microseconds.

Under saturation, the normally high resistances of the collectors change to low forward values. The transistors can then be considered as short circuits since the values chosen for resistors R_2 and R_3 are large compared with transistor parameters r_e, r_v and r_c (forward). Hence, when both transistors are saturated, the external capacitor starts to charge rapidly through resistors R_2 and R_3 in parallel. As the capacitor charges, the emitter voltage on T_1 becomes more negative. The capacitor charging time is the recovery time of the output pulse and is determined only by the sizes of the external capacitor and resistors R_2 and R_3. When the transistors are saturated, the circuit can be redrawn as in Figure 2.

Suppression action

To demonstrate the correlation between the bouncing action of an input switch and the resulting output, a hypothetical input condition is shown in Figure 3A. Assume that as the switch starts to open, it recloses momentarily due to vibration. An input waveform such as that in Figure 3A could then be observed on an oscilloscope.

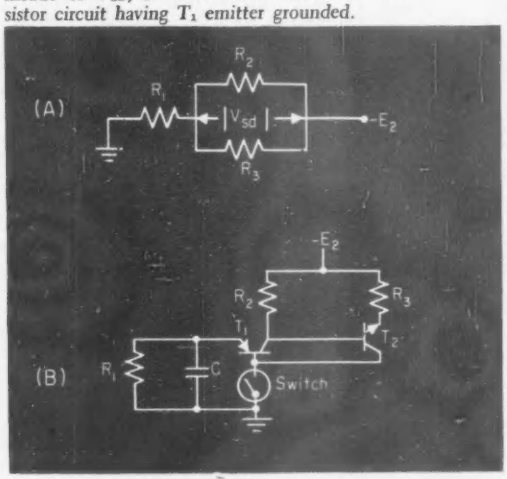
The output trace corresponding to such contact operation indicates that initially the output voltage is $-E_2$ since both transistors are cut off and there is no drop across R_3. However, as soon as the transistors fire due to the first erratic pip of T_1 base voltage, there is a large drop across the load resistors. This causes the first positive pulse in Figure 3B.

The undesirable make and break of the switch contacts produces an additional pulse at the output. The amplitude of the second pulse, however, is not sufficient to trigger the flip-flop. The maximum amplitude of the second pulse is limited by the voltage of the external capacitor at that moment and, in this case, the capacitor did not have enough time to discharge through R_1 when the contacts were momentarily closed. A long discharge time constant is, therefore, an advantage in suppression.

Design factors

When the switch is opened, the base voltage of T_1 drops from ground potential toward the negative

FIG. 4A. Equivalent circuit determining magnitude of V_{SD}; B—Alternative version of transistor circuit having T_1 emitter grounded.



collector voltage. At the same time, the collector voltage $-E_2$ rises (becomes less negative). The high point of the output pulse occurs when the two voltages approach each other and the saturation period begins. The maximum amplitude of the output pulse obtainable is independent of the circuit parameters and is limited only by the magnitude of $-E_2$.

After the switch has been opened for a certain period of time, the voltage at the output approaches $-V$ as a limit. This final value is given by:

$$-V = -\left[(E_2 - E_1)\frac{R_1R_2 + R_1R_3}{R_1R_2 + R_1R_3 + R_2R_3} + E_1\right]$$

The height of the step-down voltage V_{SD} should be kept as small as possible; it is calculated thus:

$$V_{SD} = \frac{R_2R_3\,E_2}{R_1R_2 + R_1R_3 + R_2R_3}$$

This formula is equivalent to the voltage E_2 multiplied by the ratio of $R_2\,R_3$ to $R_2 + R_3$ and divided by the resistance R_1 in series with parallel resistors R_2 and R_3, Figure 4A. The necessary condition for minimum step-down voltage is that R_1 be much greater than the ratio of $R_2\,R_3$ to $R_2 + R_3$.

Normally the emitter of T_1 is biased at E_1, a more negative potential than that of the base. An alternative circuit, Figure 4B, has an E_1 of zero (R_1 grounded). Because any small emitter current through R_1 makes the emitter voltage more negative than the base voltage, T_1 is cut off when the switch is closed. Actually, full cut-off is not achieved since some transistors conduct slightly, even though the emitter voltage is somewhat more negative than the base. The approximation is, however, quite good.

When the switch is reclosed, conduction through T_1 stops and the external capacitor begins its discharge from $-V$ to $-E_1$ (or ground). The discharge path is through R_1 since the latter is much less than the back resistance of the emitter of T_1. The discharge time constant is thus R_1C. The capacitor charging rate and the recovery time of the output pulse are determined by $R_2R_3C/R_2 + R_3$.

To suppress the erratic portion of contact action, it is essential that the discharge time be much longer than the charging period for the external capacitor. Since the size of C must be limited if the recovery time is to be of reasonable length, the long discharge time constant is usually achieved by choosing an extremely high value for R_1 (i.e., high in comparison with R_2 and R_3, but smaller than the reverse emitter resistance of T_1).

In cases where the mechanical switch operates cyclically, the R_1C time constant is made smaller than the length of time that the switch remains closed. The criterion of design is:

$$R_1C < 2/3\,t_c$$

where t_c is the length of time that the switch remains closed. If

$$R_1C > 2/3\,t_c$$

the output pulses following the first will be of lesser amplitude since the capacitor has not had enough time to discharge completely.

Figure 5 shows an actual circuit and indicates numerical values for the various parameters. With this circuit, a telephone dial has been successfully applied to trigger a transistor decade counter. The performance characteristics include a rise time of 1.8 microsec; recovery time of 270 microsec; step-down voltage of 0.15 volts; and pulse amplitude of 3.7 volts. With a different type of transistor, a rise time of 0.5 microsec has been observed. Figure 6 shows oscillograms of circuit performance.

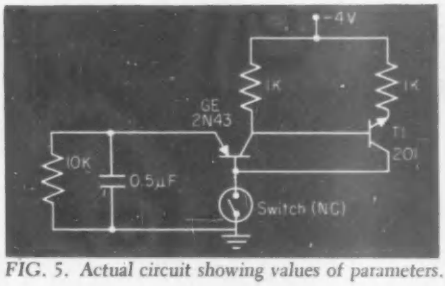


FIG. 5. Actual circuit showing values of parameters.

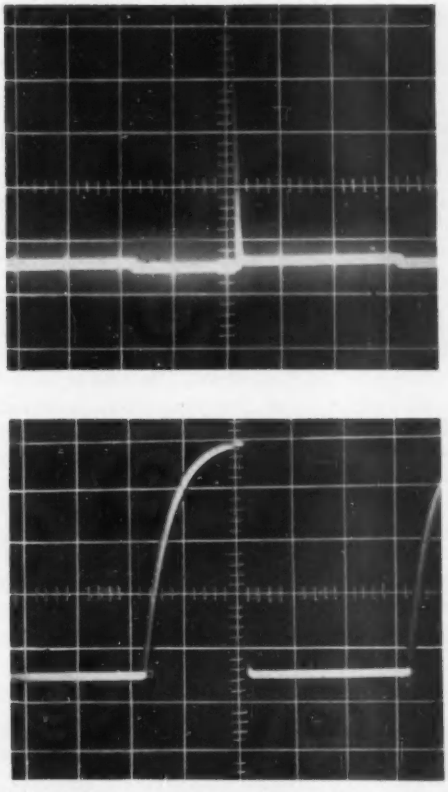


FIG. 6. A—Sharp voltage spike recorded at output terminal when switch opens. B—Capacitor voltage waveform indicating exponential discharge of capacitor through 10-kilohm resistor when switch is closed. Baseline represents value of $-E_2$.

A first-hand report on Control in British Steel

Increasing demands for steel, accented in Britain by a labor shortage, are requiring growing productivity of each steelworker. This problem is made more difficult by the increasingly stringent specifications placed by the buyer on the quality and dimensions of the steel deliverable. The 300,000-worker British steel industry is following its U. S. counterpart in turning to automatic control systems for the solution. But its approach is neither the overall systems approach advocated by many in the U. S. though practiced by few, nor the piecemeal approach practiced by most*. It is rather to apply control as well as possible to each major piece of equipment as a system in itself. The approach is illustrated here by detailed descriptions of six control systems installed recently in British mills.

DEREK BARLOW, Control Engineering, London

The past ten years have shown a record growth in British steel production, from an output of some 12.7 million tons in 1946 to 20.7 million tons in 1956. This increase of some 63 percent is all the more remarkable when it is realized that from 1939 to 1946 no capital investment was allowed and hence no new plant laid down. But in spite of this bigger production, the demand for British steel both at home and overseas is increasing steadily (in 1956 it was necessary to import some 1 million tons to meet the gap between supply and demand). A vast program of modernization and installation of new plants is under way to provide a capacity of 28 million tons by 1962.

In the U.K. steel industry the area of payoff for control systems is in the mill, since here increased operating speeds have made the human operator the slowest link in the system. The aim of introducing such systems is to eliminate the reliance on individual craftmanship, and thus unnecessary safety factors (based on a series of empirical rules accumulated in a random manner over the years), to prevent spoilage of the product. This is particularly true in forging-press operations, where the operator has to mentally integrate the velocity-time characteristic of the presshead and remove the power at the correct instant to attain the necessary displacement and position. A study of a typical machine showed that a 25 percent reduction in forging time could be achieved with use of automatic positioning control.

The British steel industry applies control systems to major pieces of equipment, such as roughing mills and blooming mills, rather than to the overall system, or in piecemeal fashion. This approach is the result of the basic research work done by the British Iron & Steel Research Association through its various committees and panels, such as the New Engineering Techniques Committee, which surveys advances in engineering science and their possible applications to industry, and the Steel Making Instruments Committee, devoted to developing instrumentation and automatic control systems.

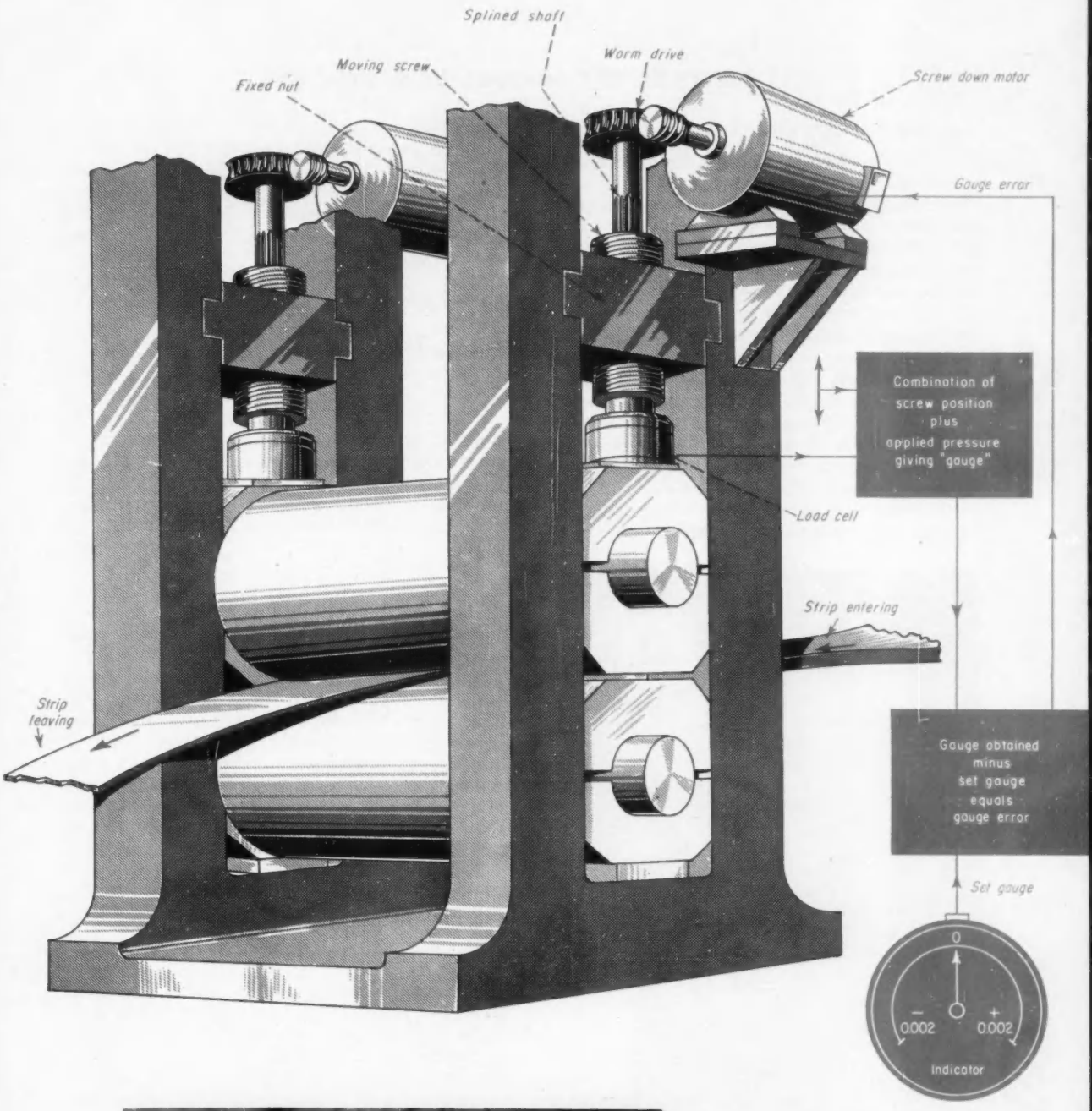
The association, which has no counterpart in the U.S., is a fine example of cooperative research supported by contributions from its 400 member firms. It is in the Electrical Engineering Section, headed by Dr. L. N. Bramley, that basic investigations are being made into the problems of applying control systems and program techniques to the industry.

Among the firsts achieved by BISRA are:

- automatic gauge control for strip mills using roll loadmeters
- automatic preset program control for elimination of rundown in hot strip
- automatic positioning control for forging presses and screwdown
- infrared width gauging
- works-performance recorder
- uniselector-type programming unit

These developments have been made available to the steel industry, and control manufacturers (of which the leaders are Metropolitan-Vickers of Manchester, English Electric of Stafford, and Davy-United of Sheffield) are engineering them into the mills throughout the United Kingdom.

* See "The Steel Industry Takes a New Look at Control", CONTROL ENGINEERING, May 1957, p. 22 ff.



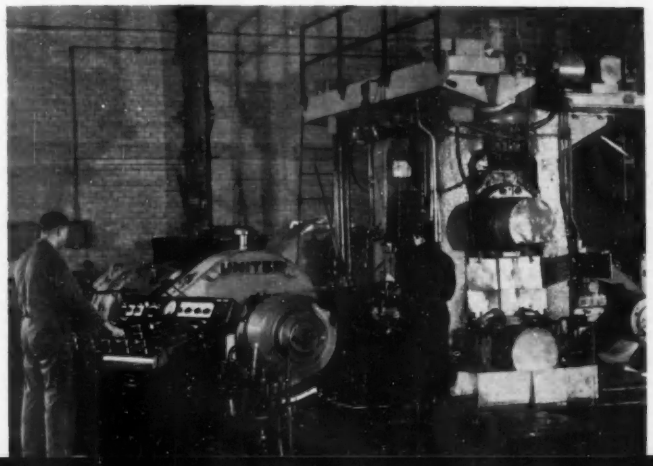


FIG. 1. Automatic gauge control system (Davy-United) uses combination of roll position and load (measured by load cell) to get gauge of strip leaving mill with no transportation lag to cause instability at low (threading) speeds.

FIG. 2. Installation of system of Figure 1 on mill at Lancashire & Corby Steel Mfg. Co., Ltd.

CONTROL TECHNIQUES IN OPERATION

Automatic gauge control

In the Davy-United system, based on original research into rolling-mill behavior by BISRA, the thickness of rolled strip can be measured right at the roll gap by measuring the screwdown position and the mill modulus. This technique, a great advance over previous methods, represents an inversion of the normal method of measuring the strip to determine what the mill has done to it: it measures by observing the forces applied by the strip to the mill.

In conventional schemes, the gauge is measured after the roll gap, and the resultant distance-velocity delay results in instability of the control system at slow speeds. This disadvantage has been overcome by measuring the roll gap itself and the load obtained from load cells beneath each of the roll screws, as shown in Figure 1. Slow drifts in the absolute value of thickness thus indicated are compensated by a supplementary radiation gage after the roll gap.

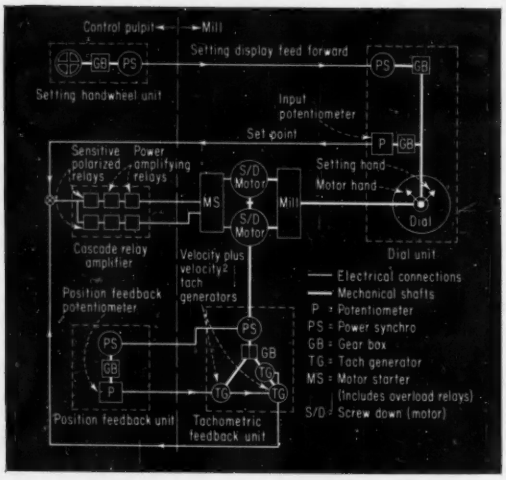


FIG. 3. Position-control system for setting roll gap uses position, velocity and velocity squared feedback to polarity-sensitive relay amplifier.

The first industrial installation (Figure 2) on a single-stand cold rolling plant was made at Lancashire & Corby Steel Mfg. Co., Northants, in 1955. The finished strip is maintained to within 0.0003 in. of gauge at all speeds, including thread speed.

All controls for the system are centralized on the control desk, where the operator is able to set up on four dials the thickness to be rolled in steps of 0.0001 in. from zero to 0.1999 in. The tolerance limits are adjustable, to suit the particular orders being rolled, in steps of plus or minus 0.001 in., plus or minus 0.0005 in., and plus or minus 0.0003 in. An overload control in this $45,000 installation lets the operator choose one of two rolling loads (240 or 400 tons) at which the controller will be disconnected.

Similar equipment has been installed for Dominion Foundries & Steel, Ltd., of Hamilton, Ontario, Can., and others are building for three British firms, Steel Co. of Wales, Northern Aluminium, Ltd., and Guest, Keen & Nettlefolds. Two more are being exported to mills in Sweden.

Preset gauge control

One of the first programming devices in the U.K. was the BISRA preset gauge control, installed at John Summers Shotton works, Cheshire, in 1951. Basic investigations showed that the strips leaving the finishing stands were consistently lighter in gauge at the front end. An analysis of the thickness trends along the strip showed that the taper was reasonably linear along its length and that it could therefore be compensated with a program of incremental screwdown corrections applied as the strip passes through the mill.

The control sequence is set in operation by the strip entering the stand and operating a load relay in the main motor circuit. As soon as this relay is energized, a uniselector (stepping relay) is stepped by an interrupter on the stand drive motor shaft. The interrupter is so arranged that one pulse is generated for every 36 ft of strip emerging from the stand. When the uniselector has rotated a set number of steps (corresponding to a preset length of material), the screwdown motors are started. The number of revolutions that they make is governed by a second interrupter coupled to the screwdown shaft, which operates a relay sequence to give the desired number of incremental correction steps of roll gap change (0.004 in. per step). After each pass the screws are reset to their original positions in preparation for the next strip.

Remote position control

A universal screwdown control system developed by BISRA was installed on a primary rolling mill in South Wales in 1956. This uses dc-energized potentiometers to determine screwdown position. The block diagram of the system, Figure 3, shows how simple it is. The desired signal and the position reference signal obtained from a potentiometer on the screwdown drive are compared in a cascade relay amplifier that uses two moving coil polarized relays to determine direction and speed range. Stabilization by a combination of velocity and velocity-squared feedback results in an overall system positioning accuracy of plus or minus $\frac{1}{32}$ in. in 30 in.

The same system has been applied to a 200-ton forging press by BISRA to preset the closure of the press to allow for further movement of the crosshead from inertia after the hydraulic supply is cut off. When forging shafts, presetting controls can be set

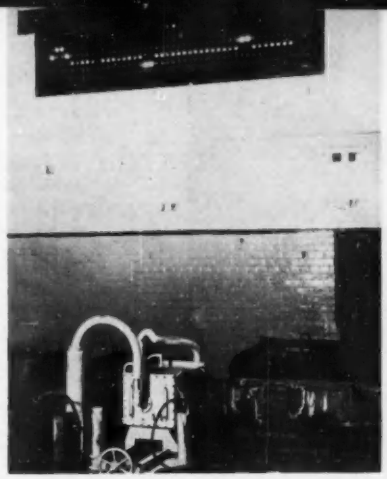


FIG. 4. Thickness readings from gamma ray gage (bottom) are integrated over 1-sec intervals to get mean values, which are indicated successively by one light in each vertical row on indicator board to show thickness profile of strip being rolled. Middle row, on tolerance; adjacent rows, just in; outside rows, out of tolerance.

to give repetitive stroking at variable speeds. In this way, a 3-in. diameter shaft can be forged to within $\frac{1}{64}$ in. without leaving marks of successive strokes.

A more accurate system with a quicker response is manufactured by Davy-United. This has phase-sensitive 400-cps carrier amplifiers and no moving coil relays (the latter can give trouble under industrial conditions), and can indicate press load.

Radiation-thickness gages

Certain companies (Baldwin Instrument Co., Ltd., of Dartford; Ekco Electronics, Ltd., of Southend Essex; and Isotope Developments, Ltd., in conjunction with Davy-United) are concentrating on the Brehmsstrahlung gamma transmission gage, which covers the range 0.020-2.00 in. A typical installation by Baldwin is the one made recently at Steel, Peech & Tozer—a subsidiary of United Steel Cos., Ltd.—for use on their hot steel strip rolling mill. It enables the operator for the first time to assess visually the overall profile of the strip from the pictorial representation of the longitudinal thickness profile displayed on the board in Figure 4.

The board has 48 vertical rows of five colored lamps. The middle one of the five indicates "on tolerance", the two adjacent amber rows within tolerance, and the outer red rows "off tolerance". The system has a 1-sec integrating period, which means that each vertical row represents the mean thickness of the strip passing through the gage during that period. The system calibrates itself automatically between strips and provision is made for manual traversing. A teleprinter produces a permanent record in digital form.

Width gauging

Automatic width measurement permits closer control of strip width and the reduction of wastage due to rolling oversize. Infrared width meters manufactured by Davy-United and Evershed & Vignoles of London have been developed from work done by BISRA, and are claimed to be cheaper and more accurate than their U.S. counterparts.

The systems consist mainly of two follower units, each indicating variations in position of the strip edge. These variations are summed algebraically, as shown in Figure 5, to give a net variation in width. In each of the follower units, two lead-sulfide cells pick up radiation from, respectively, the strip edge and a reference area adjacent to the edge. A servo system operates a movable shutter to balance the signal received from the strip edge against that received by the reference cell, so that effects of transverse temperature variations in the strip are canceled out and variations of cell sensitivity with temperature are minimized. The output of the followers is combined in magslips (synchros) connected to give width deviation from the desired value.

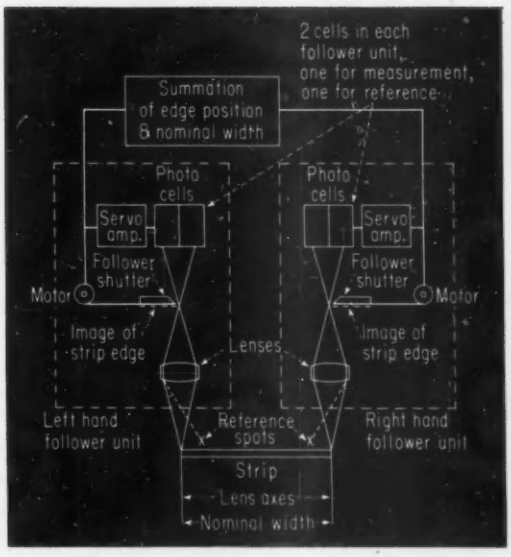
This system, in use at The Steel Co. of Wales, is capable of an accuracy of plus or minus $\frac{1}{8}$ in. over a range of plus or minus 3 in. in the nominal width, which can be adjusted to production requirements.

Work-performance recorder

A multichannel punched-tape performance recorder designed by BISRA has been installed in a mill in South Wales to monitor 18 rolling mills and other heavy plant. Each order rolled is designated by an order number against which the running time, idle time, and stoppage time are recorded for every delay exceeding 1 min. The recorder has two "accumulators", one recording running time and the other idle time. A "clock" delivers pulses every 3.6 sec (1/1000 hour) which are routed to either of these accumulators by a relay on the mill, Figure 6.

The operator has a set of pushbuttons, Figure 7, for recording the code number of each order and

FIG. 5. Width measurement system sums variations in both edges to find change in width.



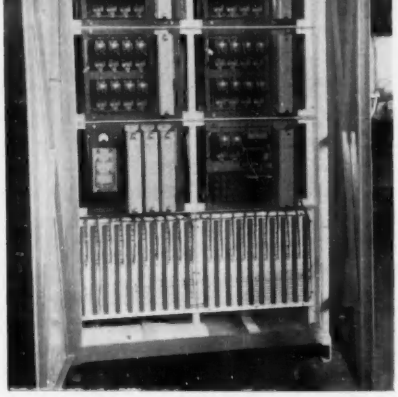


FIG. 6. These "accumulators" are the heart of BISRA works performance recorder. One records idle time, the other running time. Queueing section at bottom right remembers orders received simultaneously, carries them out in sequence.

FIG. 7. Pushbutton operator's station for works-performance recorder.

the stoppage code number. An "incident button" is included in the control console for printout of the stored data and clearing the accumulators. As soon as the previous order in the sequence of operations on the mill has been cleared, idle time will begin to accumulate in the idle-time accumulator. When a new order is received the code number is set up, and as soon as rolling begins the time pulses are switched automatically to the running-time accumulator. The data is recorded on tapes and cards simultaneously and can be transcribed automatically and printed out on a standard teleprint page. Additional features of the installation: "queueing device" for operation on up to 25 machines–if the incident buttons of more than one machine are pressed simultaneously the recorder reads out in sequence; a time switch, which permits accumulated totals to be read out at the end of each shift, leaving the order number or fault number unchanged.

Programming systems

In their survey of practical programming systems, BISRA concluded that punched-card techniques were too inflexible for British steel. The U.K. industry needs extreme flexibility because, in a typical mill, the length of run for any particular order may be as short as 10 min. Metropolitan-Vickers and English Electric are presently working with BISRA on program systems for future installations.

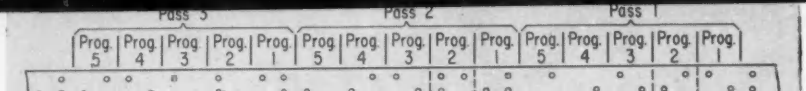
The English Electric programming system incorporates the BISRA "translator control" instead of punched cards or tape. This system has built-in programs and automatic program selection. The translator is divided into three sections: input, link, and output. The input correlation section uses uniselectors (stepping relays) so connected that they rotate to find a position corresponding with each significant configuration (code) of input data. A uniselector wiper position is provided for each input configuration, and although the input configuration can be searched for simultaneously by a number of uniselectors, the unique position corresponding to the input data will be found on only one. The link with the output uniselectors is via a correlation circuit comprising a number of wires equal to the number of significant configurations of input data –in fact, the function of the input section of the translator is to identify each input state by a separate wire. The output section may use several uniselectors to identify the wire previously selected by the input section and these are wired so that they stop rotating at the step defined by the input state. The remaining levels on the output uniselectors are then used for switching drive contactors and providing various digitally coded references for position control. See Figure 8.

Although this system is complex because of the interconnection wiring between the input and output uniselectors, it lends itself to fully automatic mill operation and to the possibility of continuous optimization. For example, the measurement of roll motor load can be used to alter the number of passes during rolling, while the ingot size and final bloom size can be scheduled from the office.

On receipt of the input data regarding ingot size, final bloom size, and number of passes required, the English Electric-BISRA system specifies for each pass the screwdown setting, whether tilt is required, the rollhole setting, and the roll speed. With four input switches, the operator can select the number of passes from 11-15, the choice of a 5- or 7½-ton ingot, and the final size of bloom from 7 by 9 to 12 by 16 in. in 1-in. increments. From this data a program is selected by the motor-driven uniselectors in the translator unit, which provides a 10-binary digit output for screwdown position, a 1-in-5 selection of rollhole, and an on-off decision for tilt. Up to 150 programs can be built into the translator, which is so flexible that the program can be changed while the billet is being rolled. Telephone-switching techniques are used instead of electronic methods to assure reliability with simplicity and ease of maintenance by nonspecialist personnel.

Another approach

Following the same basic philosophy of providing the utmost flexibility is Metropolitan-Vicker's punched-tape input system. In its simplest form the



M-V system provides five programs of up to 20 passes each and was intended for screwdown control only. But it can be expanded. A special tape reader was made from a high-speed motor uniselector by adding a suitably geared tape driving sprocket wheel and a photo-transistor reading head. Screwdown setting data is coded on a loop of tape, as shown in Figure 9. The motor uniselector contacts are wired in similar groups to a homing circuit, so that switching the supply voltage from the first contact of one group to the first contact of the next group with a five-bank ratchet-type uniselector causes the tape to move one pass-pitch forward. The program switch selects one bank of the ratchet uniselector, which controls the position of the tape within the group of the data for one pass and can be operated at any time in the rolling schedule.

The screwdown setting can be defined to an accuracy of 0.2 percent using nine binary digits. This is adequate for the blooming mill. The tenth hole is used as an "end of program" signal which automatically resets the tape reader and screwdowns to "standby" if less than the maximum number of passes is required. Operation of the master control button (Figure 10) causes the phototransistors to interrogate the tape. The digital information is converted to analog form by transistor-operated relays switching binary-weighted resistors in a constant-current chain. The analog voltage is then used as a reference for the servos. When the servo error becomes zero, the control circuit uniselector is energized to step the tape reader homing circuit and the tape loop one pass-pitch forward ready for the next pass. The tape preparation can be done on a standard teleprinter with the aid of a table giving screwdown settings in terms of teleprinter letters; duplicate tape readers are provided for utmost reliability. To change the range of programs other tape loops are stored in cassettes.

The tape-programming unit provides the positional reference signal for a remote positioning Ward-Leonard system, in which the generator split field excitation is controlled by a magnetic amplifier (Figure 11). By means of input signals to the magnetic amplifier that combine the square root of the error signal and the relative velocity signal, the screwdown settings are reached in minimum time. The system is stabilized by transient motor voltage feedback and the overall accuracy of the system is plus or minus 1 part in 800.

A LOOK AHEAD

With these techniques available, what of the future from the steel industry and control manufacturers' viewpoint? All the large steel producers (such as Stewarts & Lloyds, Ltd., United Steel Cos., Ltd., The Steel Co. of Wales, Colvilles, Ltd., John Summers & Sons, Ltd., and Dorman Long, Ltd.) have sophisticated control schemes under study, some in their own R&D departments and others in conjunction with BISRA. Typical are:

▶ Study of optimizing the cutting of billets to var-

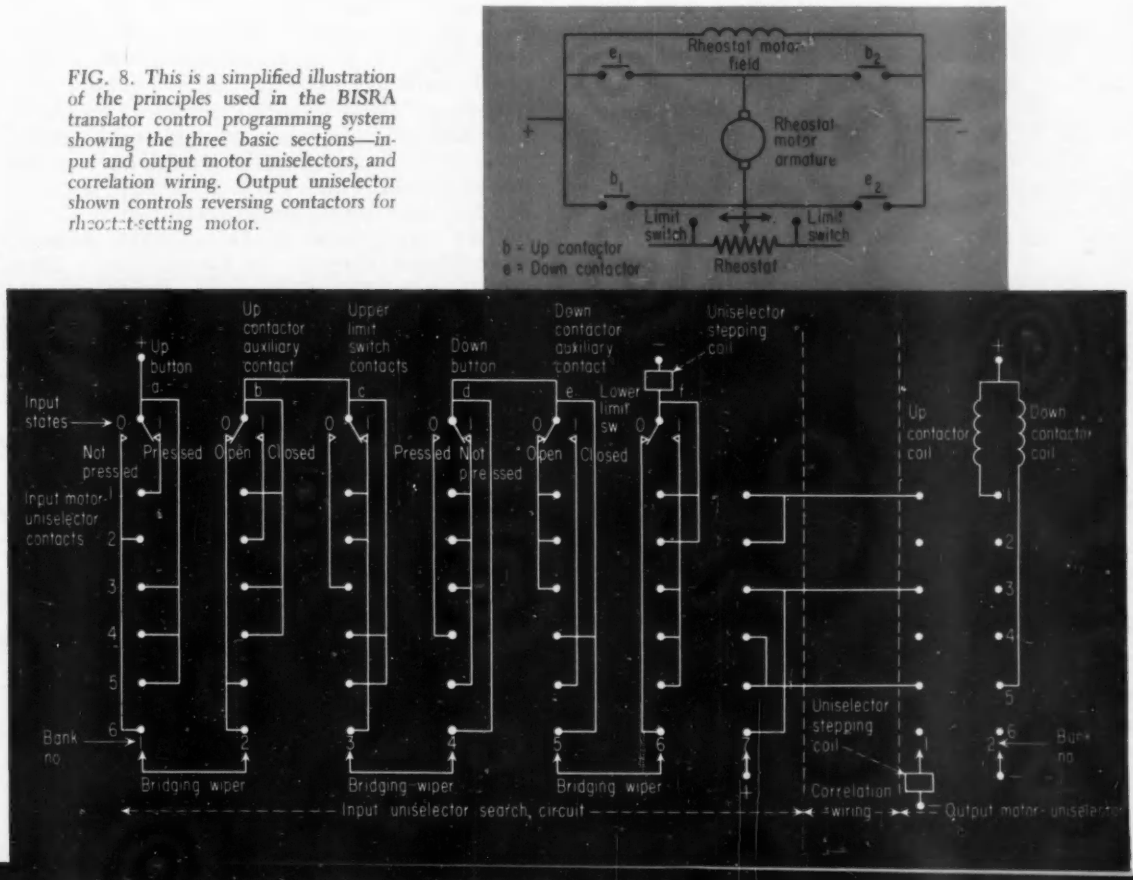


FIG. 8. This is a simplified illustration of the principles used in the BISRA translator control programming system showing the three basic sections—input and output motor uniselectors, and correlation wiring. Output uniselector shown controls reversing contactors for rheostat-setting motor.

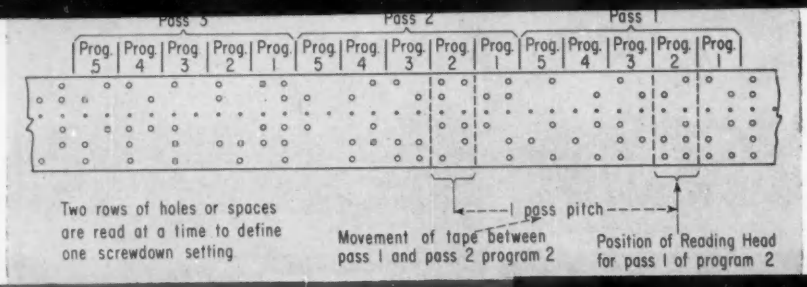


FIG. 9. Punched-tape coding format used in Metropolitan - Vickers' programming system.

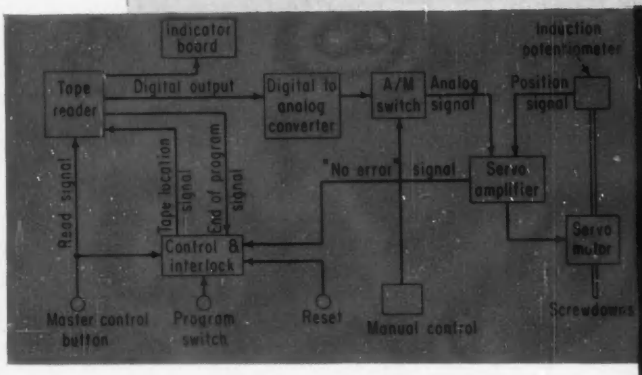


FIG. 10. Tape of Figure 9 is used in this system for programmed screwdown control. Operation is described in text.

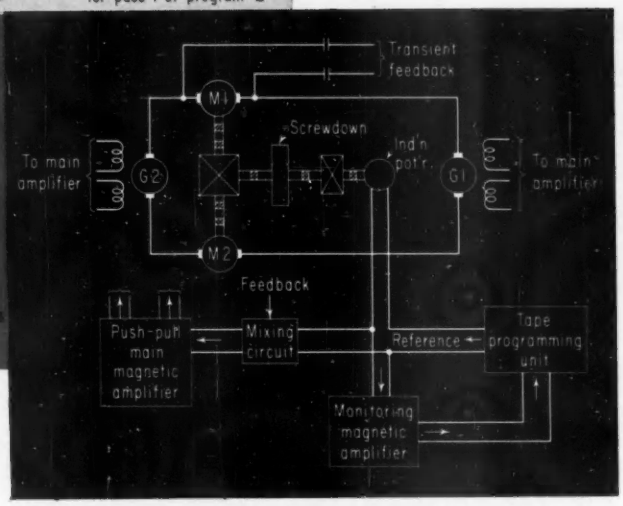


FIG. 11. Screwdown actuator for programmer of Figure 10 is Ward-Leonard system using magnetic-amplifier field control.

ious lengths and computing for shrinkage and saw thickness.

▶ Installation of a tape-program control for rolling mills, due to go into operation in 1958.

▶ Automatic length cutter with an accuracy of ½ in. in 60 ft, using infrared measuring heads, a programmed input device, and temperature-correction.

▶ Optimization of mill performance where continuous measurement of the parameters will weight a built-in program or compute its own program.

▶ Development of radiation thickness gages for profile measurement of round bar and automatic transverse thickness measurement of strip.

United Steel Cos., Ltd., heads the list of the major steel producers studying these problems. It is the first company in the world to apply cybernetics —in its new Operational Research & Cybernetics Dept.—to the steel industry. This department, running at an annual cost of $300,000, solves problems in logic and is unfolding a philosophy of

1. Optimize the plant
2. Optimize the yield
3. Control the product

to get away to a head-start. This philosophy means the gradual adaptation of control devices to specific pieces of mill equipment rather than overall, for United Steel says that "before an overall system can be envisaged we must be able firstly to measure what we want reliably, and then display the results in the most suitable form for the operator to make effective control. Then from that stage on, with a knowledge of the parameters we can apply automatic control." Their view on electronic control gear is shared by many firms.

The lack of suitably trained maintenance men, still a real problem, will become even greater as more automatic control is installed. Today, if the control system breaks down, the operator can run the mill manually, but what will happen in the next generation? United Steel likens the problem to that of the man used to an auto with an automatic gearbox who is confronted with the old-style gear lever.

Reliability is improving now that control manufacturers are appreciating that equipment built for military reliability won't hold up under 24-hours-a-day continuous operation for many years. During the 1946-50 era, however, when military equipment makers began entering the industrial field, there was no appreciation of these special problems.

A. Asbury, chief engineer, Control & Electronics Dept. of English Electric, confirms this when he says, "The steel industry are now sympathetic co-operators in control systems." As a control builder, Asbury's view is that the installations of the past four or five years have paved the way for full automatic control and it is now possible to control all sections of the mill electrically. The units that operate as an entity will increase in size while the programming techniques will retain their flexibility.

This approach, while less adventurous than the overall system approach, is held in Britain to be the right one—placing less of a strain on management and on the unions. There is no doubt that this is the way that control will advance in British steel.

Guide to Costs of

Industrial Temperature Measurement

HOWARD R. KALBFLEISCH, New Hyde Park, N. Y.

Selection of equipment for measuring or controlling temperature involves such factors as range and desired accuracy, the sensing element to be used, and the type of systems under consideration. Each of these factors influences cost, and since more than one equipment arrangement may satisfy particular system requirements, it is important to determine which one costs the least. The tables that follow will guide selection of temperature measuring and controlling equipment according to cost.

Table 1 shows the working range for common temperature-sensing elements, and Table 2 the cost of various instrument arrangements or control loops, based on direct-connected, pneumatic, and electronic systems. This latter table also relates cost to the element that can be used, and the expected limits of error. The diagram (Diag.) referred to here is shown on Table 3, which shows the instrumentation and control elements included in the pricing of a corresponding system in Table 2.

FOLLOW THESE STEPS

- ▶ Select in Table 2, columns A and B, all alternatives for temperature (or temperature range) to be measured or controlled.
- ▶ Note in column C the limits of error (accuracy) for each alternative and choose the one most suitable to the application.
- ▶ Move across the table from temperature range and accuracy to column D, which shows the costs of particular functions and then corresponding connection and components diagrams in Table 3.

If the arrangement selected in this way is not satisfactory in cost, accuracy, sensing element, or type of system, then move to the right or left, up or down, to select a better one.

COSTING GROUND RULES

The system costs shown in Table 2 reflect the use of high-quality equipment. Of course, additional features such as alarm contacts will increase costs. An example for a thermocouple-operated temperature indicator-controller (Diag. 15), shown below Table 3, demonstrates how these costs were obtained. The prices are as of August 1957.

The costs in Table 2 cover:

- Normal industrial temperature measurement service.
- Single-point, panel-mounted recorder, miniature size where applicable, otherwise conventional or spring-driven. (Multipoint recording will reduce average cost per recorded point.)
- Thermocouple; where used, it is 6 in. of B & S 24-gauge platinum-rhodium wire. Subtract $55 for copper-constantan, iron constantan, or chromel-alumel couple.
- High-quality air- or electrically-operated 1-in.-size valve.
- Wiring or plastic tubing between sensing element and instrument panel (100 ft), transmitter and panel (100 ft), and panel and valve (100 ft).
- Outlet box or air set for connecting to electrical power lines or air supply.

The costs do not include:

- Installation or operation
- Explosion-proofing
- Special calibration
- Special materials for corrosion resistance

Table 1

RANGES FOR TEMPERATURE-SENSING ELEMENTS

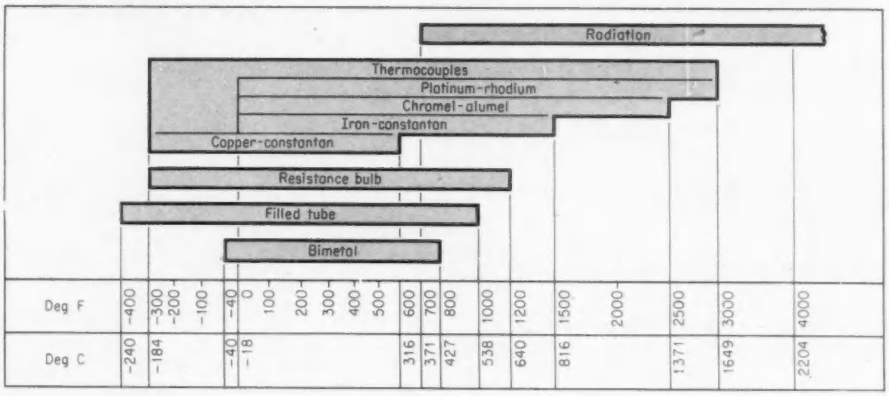
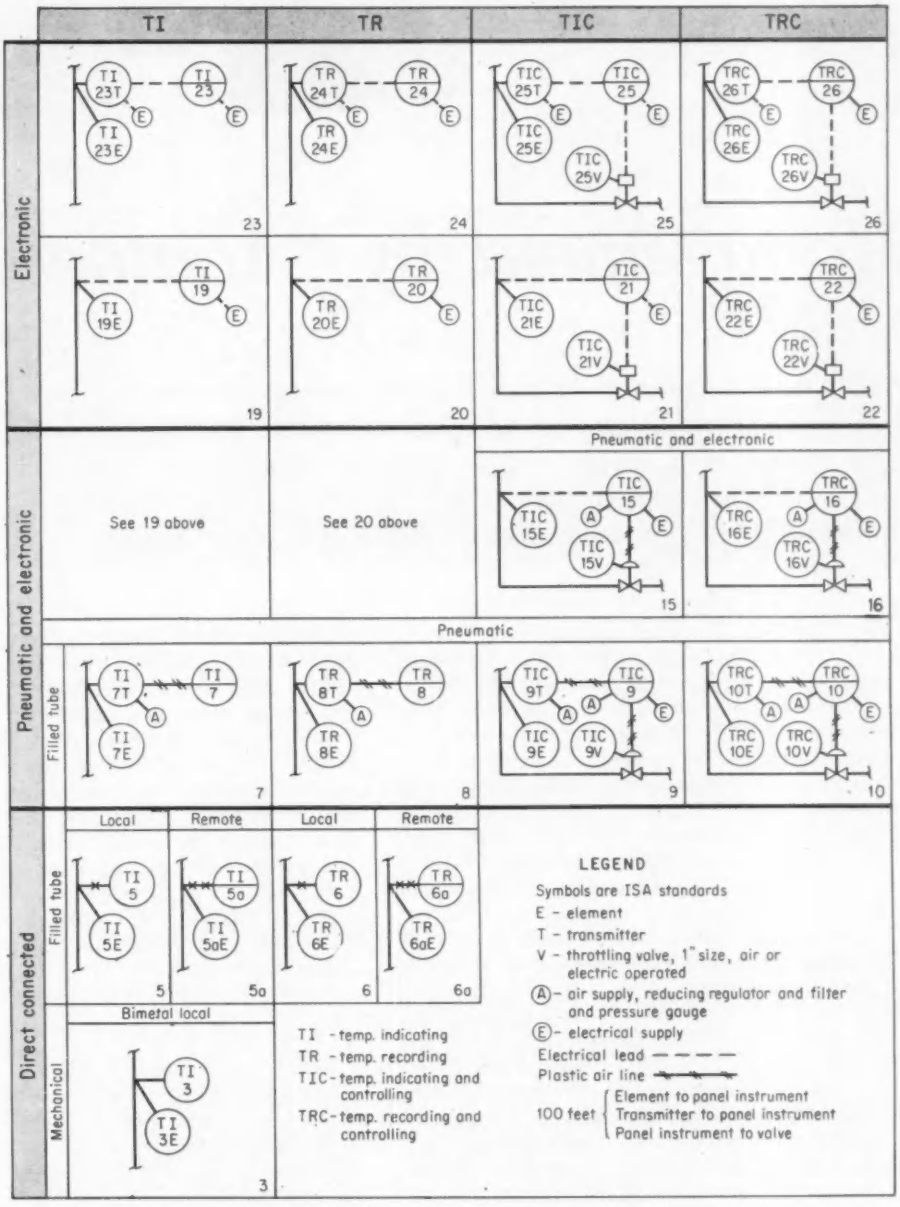


Table 2 COMPILATION OF COSTS

A		B			C	D				
Range °F		System			Limits of error		Instrument function or loop			
Low	High		Element				TI	TR	TIC	TRC
700	4,000	Electronic	Radiation		Depends on installation	$	630	980	1710	1955
					(Roughly 1%)	Diag.	19	20	21	22
-300	1,200		Resistance		1/4 to 1%	$	485	645	1235	1335
						Diag.	23	24	25	26
-300	2,800		Thermo-couple		1/2 to 4°F	$	475	640	1230	1330
						Diag.	23	24	25	26
						$				
						Diag.				
700	4,000	Pneumatic and/or electronic	Resistance		Depends on installation	$	Electronic		Elec. and pneu.	
					(Roughly 1%)	Diag.	See 19 above	See 20 above	1600	1890
									15	16
-300	2,800		Thermo-couple		1/2 to 4°F	$	Electronic		Elec. and pneu.	
						Diag.	410	760	1385	1670
							19	20	15	16
-300	1,200		Resistance		3/4 to 1 1/2°F	$	Electronic		Elec. and pneu.	
					1/4 to 1%	Diag.	405	655	1375	1665
							19	20	15	16
-400	1,000		F.t.	Gas bulb	1/2 to 1%	$	Pneumatic			
						Diag.	270	430	780	915
							7	8	9	10
-40	800	Direct connected	Filled tube	Mercury bulb	Up to 1%	$	Local 125	Remote 205	Local 230	Remote 315
						Diag.	5	5a	6	6a
-125	800			Gas bulb	1/2 to 1%	$	115	200	225	310
						Diag.	5	5a	6	6a
-40	800		Mech.	Bimetal	Up to 1%	$	33			
						Diag.	3			

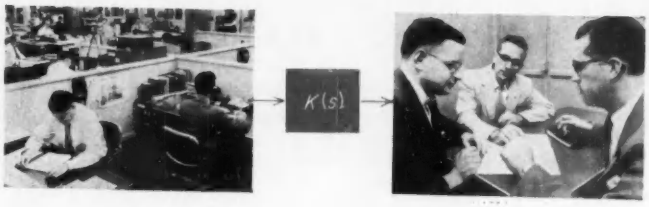
Table 3 ELEMENTS AND CIRCUITS



COSTING EXAMPLE

The cost of the thermocouple-operated TIC of diagram 15 is $1,385; the breakdown follows:

1	1-in. air-operated diaphragm valve	$185
1	6-in. platinum-rhodium couple and well assembly	75
100 ft.	of extension lead wire, (no conduit)	30
1	indicating potentiometer controller with air control . . . proportional plus reset plus rate action . . . manual control panel	1,062
100 ft.	of plastic tubing	10
1	air set, reducing regulator, filter and gage	14
1	electrical power supply (outlet box, socket, etc.)	5
		$1,381



Management by "Analoging"

Here is how a transfer function can be derived and used to determine the relationship between engineering effort and sales. Viewing the company as a servo system is a useful tool in planning other company activities, too.

GORDON K. JOHNSON, Aeronautical Div., Minneapolis-Honeywell Regulator Co.

Many companies whose products and services are of a technical nature have difficulty determining the amount and timing of engineering effort needed to support sales forecasts. The sales future of these companies is closely related to their engineering programs, and an understanding of this relationship is invaluable in optimizing engineering effort. The relationship can be studied by making an analogy between the company and a servomechanism. Engineering effort is the input to the system; sales is the output. Then the two quantities can be related by a transfer function, $K(s)$.

Since some of these products suffer from high obsolescence rates and must be tailored to highly specialized requirements, their sales can be maintained only by continuous modifications. The rapidly developing avionics industry illustrates this well. For example, a system designed for a particular series of aircraft frequently must be redesigned completely and refitted before it can be used in another series with similar characteristics.

The key to satisfactory sales and economic production is a properly planned engineering program. Improper magnitude and timing of engineering effort for such products cause a highly variable production rate and consequently higher production costs.

I. Definitions

The first step in developing $K(s)$—relating engineering effort and sales—is to define the quantities so that existing data can be analyzed. Defining sales as the dollar value of products shipped avoids accounting difficulties associated with cancellations, billings, and adjustments for accounts receivable, and automatically weights various devices with respect to their engineering complexity. The definition has the disadvantage, however, of eliminating some engineering effort from consideration: for example, design work on products which are never sold.

This definition of sales forces the definition of engineering effort to include the activity only on those devices that finally sell. And those phases of effort that cannot be assigned to a specific device, system, or product are eliminated from the consideration in the term "engineering effort". Examples include research and production engineering.

But these activities cannot be neglected. Though their inclusion in the engineering-sales relationship would complicate the transfer function and make it difficult, if not impossible, to define the behavior of the organization in mathematical terms, they should be investigated separately.

II. Analyzing historical data

Before the transfer function can be expressed mathematically, typical engineering effort and the corresponding sales must be defined. This was done by studying historical data on devices sold over an eight-year span. The engineering effort and sales data for each device were tabulated on a calendar-year basis. To obtain a curve representing a typical engineering effort and the corresponding sales, all sets of data were shifted in time so that the peak engineering effort coincided for all products. The curves for three of the products are shown in Figure 2.

Typical engineering effort and sales curves were obtained from this composite of repositioned curves by computing the geometrical means of all engineering effort curves and all sales curves, respectively. The resulting typical curves are shown in Figure 3. These computed curves represent a typical input with a corresponding typical output. With this information, a transfer function can be derived.

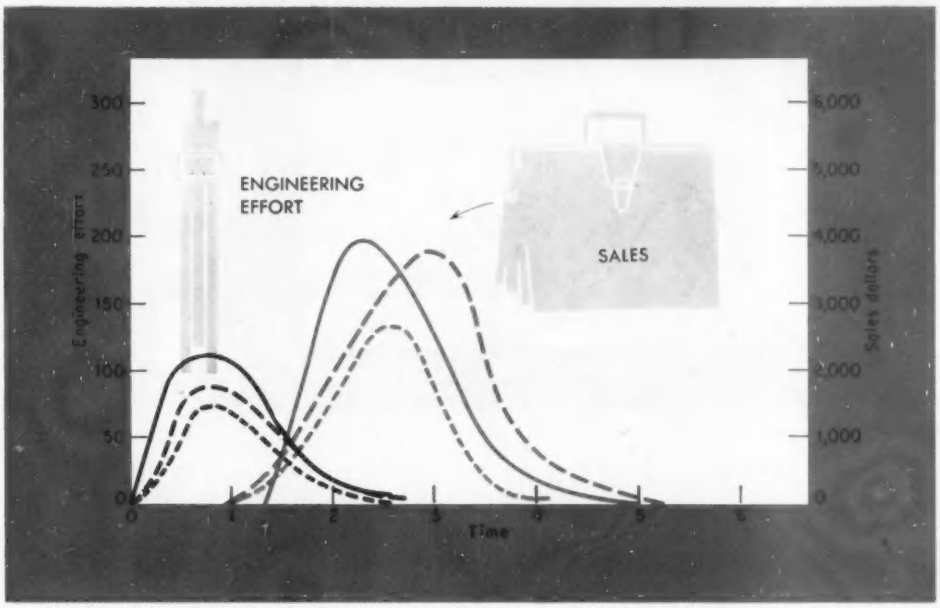


FIG. 2. Engineering effort and sales curves for three products.

III. Deriving the transfer function

The transfer function is the ratio of the Laplace transform of the output to that of the input.

$$K(s) = \frac{\int_o^\infty e^{-st} E_o(t)\, dt}{\int_o^\infty e^{-st} E_i(t)\, dt} \qquad (1)$$

where $K(s)$ = transfer function; $E_o(t)$ = sales output; and $E_i(t)$ = engineering input.

To avoid difficulties in working with the transfer function, $E_o(t)$ is shifted in time so that $E_i(t)$ and $E_o(t)$ reach nonzero values at the same time. This eliminates the consideration of a system with a constant time delay and makes it easier to transform from the t plane to the s plane and back again. Shifting the output in time before the transfer function is derived merely means that subsequent use of the transfer function will yield answers that have been shifted in time by the same amount. An opposite time-shift corrects the answers.

Before Equation 1 can be used to obtain a transfer function from the curves of Figure 3, analytical approximations must be made for $E_o(t)$ and $E_i(t)$.

Fourth-degree polynomials developed by means of a least-squares fit have sufficient accuracy for this study. Polynomials simplify the evaluation of the integrals of Equation 1 and the subsequent use of the transfer function, but they limit the time span over which the transfer function is valid. If the polynomials are fitted over the entire time span of interest, this approximation causes no difficulty. By using fourth-degree polynomials, the transfer function, $K(s)$, was reduced to the form:

$$K(s) = \frac{a_4 s^4 + a_3 s^3 + a_2 s^2 + a_1 s + a_o}{b_4 s^4 + b_3 s^3 + b_2 s^2 + b_1 s + b_o} = \frac{P(s)}{Q(s)} \qquad (2)$$

and had four positive poles. The transform of a sales response, $O(s)$, to an arbitrary engineering input, $I(t)$, can now be obtained by multiplying the transfer function by the transform of the input:

$$O(s) = K(s) \int_o^\infty e^{-st} I(t)\, dt \qquad (3)$$

The engineering input, $I(t)$, was approximated with a polynomial of fourth degree. Thus,

$$I(t) = c_o + c_1 t + c_2 t^2 + c_3 t^3 + c_4 t^4 \qquad (4)$$

and its transform

$$I(s) = \frac{1}{s^5}\,(24c_4 + 6c_3 s + 2c_2 s^2 + c_1 s^3 + c_o s^4) \qquad (5)$$

From Equation 3, $O(s)$ then becomes a rational function of s with a multiple pole of order 5 at zero, plus the same four positive poles of the transfer function.

$$O(s) = \frac{I(s)\,.\,P(s)}{Q(s)} = \frac{(24c_4 + \ldots + c_o s^4)\,.\,P(s)}{s^5 Q(s)} \qquad (6)$$

The partial fraction expansion of $O(s)$ is expressed:

$$O(s) = \frac{A}{s^5} + \frac{B}{s^4} + \frac{C}{s^3} + \frac{D}{s^2} + \frac{E}{s} + \frac{Fs^3 + Gs^2 + Hs + J}{Q(s)} \qquad (7)$$

From the theory of the statistical design of predictors, the last term of this expression can be discarded because it contains only positive poles. The time span for errors thus introduced is short, while the time span of historical data considered in the use of the transfer function is relatively long. The fact that this term can be discarded greatly simplifies programming the procedure for a digital computer. Solving for the constant of Equation 7,

$$A = \frac{1}{b_o}\,(24a_o d_4) \qquad (8)$$

$$B = \frac{1}{b_o}\,(6a_o c_3 + 24a_1 c_4 - Ab_1) \qquad (9)$$

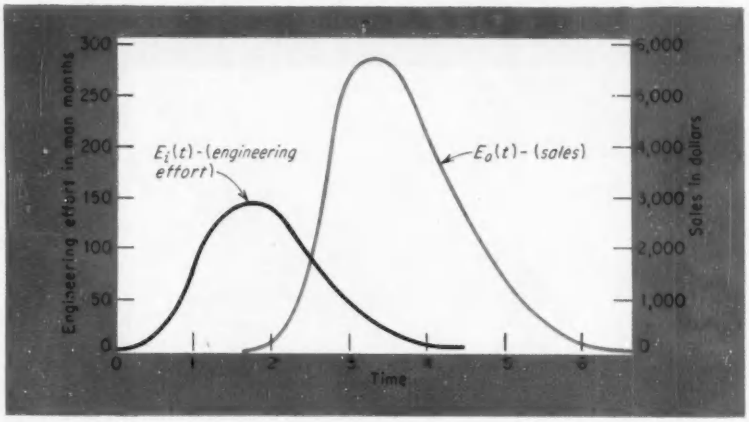


FIG. 3. Typical engineering effort and the corresponding sales.

$$C = \frac{1}{b_o}(2a_oc_2 + 6a_1c_3 + 24a_2c_4 - Ab_2 - Bb_1) \quad (10)$$

$$D = \frac{1}{b_o}(a_oc_1 + 2a_1c_2 + 6a_2c_3 + 24a_3c_4 - Ab_3 - Bb_2 - Cb_1) \quad (11)$$

$$E = \frac{1}{b_o}(a_oc_o + a_1c_1 + 2a_2c_2 + 6a_3c_3 + 24a_4c_4 - Ab_4 - Bb_3 - Cb_2 - Db_1) \quad (12)$$

$O(t)$ can now be expressed in terms of these constants. Finding the inverse transform of $O(s)$ with the last term discarded, $O(t)$ becomes

$$O(t) = E + Dt + \frac{Ct^2}{2} + \frac{Bt^3}{6} + \frac{At^4}{24} \quad (13)$$

Using Equations 8 through 12, the coefficients of the fourth-degree polynomial representing the desired output, $O(t)$, become functions of the coefficients of Equations 2 and 4, the transfer function and the polynomial approximation to the input.

IV. Using the results

The entire computational procedure can (and has been) programmed for an IBM 650. In combining a polynomial least-squares fit program with a program for the coefficients of Equations 13 and a polynomial evaluation routine, only the magnitude of engineering effort for each unit of time, along with the coefficients of the transfer function, must be given to the digital computer. The computer then computes the corresponding output for each unit of time. The sales output of the program must then be shifted in time, as has been discussed, to get the sales per year for corresponding engineering effort. Total computation time is approximately 4 min per problem. The program is general enough to be used for similar problems.

The engineering effort determined by the transfer function is defined as "effective design and development engineering". Before the transfer function can be used to plan the total engineering program, the relation of total engineering to effective design and development engineering must be known. It was found from historical data that the ratio of these quantities increased each year along an 82.5-percent learning curve. The total engineering program at any given time can now be determined from engineering effort, as defined for the transfer function analysis.

To check the validity of this transfer function, a comparison is made between actual past sales and computed past sales based on recorded total engineering effort. The deviation between the two sets of data is found to be less than 5 percent.

V. Extending the analogy

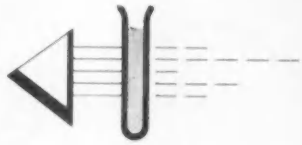
The transfer function analogy can also assist in an understanding of the amount and timing of engineering effort needed to meet sales forecasts. Consider expected or desired sales as the input to a system and the engineering effort as the output. The transfer function for this new system is the reciprocal of the transfer function derived above. Then for a given sales forecast, the amount and timing of engineering effort needed to support these sales can be computed and used to make decisions on hiring programs and facility plans. A sales forecast not based on a carefully supported engineering program can lead to difficulties. The transfer function provides a cross check on sales forecasts, exposing those that are too high or are not properly timed for the engineering program.

One logical extension of its application is to derivations of separate transfer functions for each product line. Combining these with the proper conditional relationships gives management a powerful aid in finding an optimum mix of product lines.

It also appears feasible to use transfer functions to relate sales to other planning variables, such as capital expenditures, production manpower, production engineering, and research.

REFERENCES

1. *CONTROL SYSTEM SYNTHESIS*, J. G. Truxal, McGraw-Hill Book Co., Inc., New York, 1955.
2. *USE OF TRANSFER FUNCTIONS FOR COMPANY PLANNING*, G. K. Johnson and I. M. Turner, Operations Research, Vol. 4, No. 6, pp 705-710.
3. *THE MECHANISM OF ECONOMIC SYSTEMS*, A. Tustin, Harvard University Press, Cambridge, Mass., 1953.
4. *ANALOGUE COMPUTATIONS OF BUSINESS DECISIONS* W. R. Fair, Operations Research, Vol. 1, No. 4, pp 208-219.



PHOTOMETRIC STREAM ANALYZERS —

versatile instruments for measuring composition

The term photometric analyzer covers ultraviolet and infrared analyzers, colorimeters, and refractometers. Author Glasser begins by taking a broad look at the applications of all these instruments, describing their fundamentals and suggesting how to select them, and then gets down to the details of one type—ultraviolet analyzers. Here he covers the basics of operation, describes commercially available instruments, and shows how to achieve selectivity and sensitivity. One table lists liquids and gases that can be measured with ultraviolet; another lists those that cannot be detected with ultraviolet and whose presence in the sample does not therefore constitute interferences.

Next month the discussion of photometric analyzers continues with du Pont's Dan Troy writing about infrared analyzers.

LEO G. GLASSER
Engineering Research Laboratory,
E. I. du Pont de Nemours & Co., Inc.

Before examining the three photometric analysis techniques it is important to define, at least broadly, the application areas of each type. Later in this article the application details of the ultraviolet analyzer and the specific materials it can analyze will be discussed. Subsequent articles will treat infrared analyzers and refractometers in the same way.

Two important analyzer criteria are sensitivity and selectivity. Many substances absorb ultraviolet radiation at a specific monochromatic wavelength, and in a mixture of several components it is not too easy to determine whether a change in absorbance is due to a change in concentration of one component or another. Furthermore, ultraviolet absorptions of most materials characteristically occur in broad bands of wavelengths and the bands for several materials in a mixture may overlap each other. On the other hand, a substance subjected to infrared radiation absorbs it at one or more distinct narrow bands of wavelengths, and different materials have distinctive infrared absorption patterns. Thus, the adaptation of an analyzer to respond to a single substance in a mixture is relatively difficult with ultraviolet and easy with infrared.

But while infrared analyzers are more selective than ultraviolet analyzers, the opposite, generally speaking, is true for sensitivity. One reason for this is that the absorption of a substance at the wavelength where it is strongest is more intense than the absorption of that substance at any infrared wavelength.

Ultraviolet analyzers

Ultraviolet analyzers find their greatest application in gases and liquids, but have been used to a limited extent on solids. Available types can be applied to:

- measuring broad or exceedingly narrow ranges of concentration;
- operating at visible (colorimeters) and near-visible wavelengths only, or at these and ultraviolet wavelengths down to the limit where oxygen begins to absorb;
- analyzing with broad (continuous) or narrow (monochromatic) bands of radiation; all with a variety of sampling and electronic arrangements.

An ultraviolet analyzer is generally preferred over an infrared analyzer, when either might be used, for these reasons: most ultraviolet analyzers are simpler in design, require less maintenance, and have higher sensitivity than infrared instruments. The best ultraviolet analyzers detect concentration changes (sensitivity) as small as a few parts per billion and are restricted mainly by variations in concentration of unsuspected contaminants. Analyzers normally have a linear response to changes in gas density so that large fluctuations of temperature and pressure appear as errors in measured concentration. This difficulty is not so pronounced with liquid samples.

Like other analyzers, ultraviolet analyzers are useful only when a change in process-stream composition produces a comparable change in the sample's radiation-absorption properties, and the analyzer responds as if only one component at a time is varying. An ultraviolet analyzer can handle not only a variety of multicomponent samples but simple two-component (binary) samples to which a refractometer usually is applied. For some binary samples an ultraviolet analyzer offers up to a 1,000-times-higher sensitivity than a refractometer.

Infrared analyzers

Though infrared analyzers mainly handle gases, a few adaptations for liquids have been made. None has as yet been built for measuring solids and turbid samples. In most infrared applications the concentration is recorded for one gas or vapor in a multicomponent mixture. Available infrared analyzers are competitive, broadly speaking, with ultraviolet analyzers, but not to a great extent with refractometers, which are limited to binary mixtures.

Infrared process-stream analyzers are of two basic types: self-filtering, which employs one or more selected bands of infrared wavelengths; and monochromatic, which employs one or more discrete wavelengths. The former includes positive- and negative-filtering types, and several variations, combinations, and extensions of these have become available as a result of efforts to achieve selectivity. Monochromatic analyzers employ either optical filters (only at short infrared wavelengths) or spectroscopic (prism) dispersion.

As in the case of ultraviolet analyzers,

the applicability of infrared analyzers can only be predicted after a complete qualitative and quantitative analysis of the process stream and with the help of absorption spectra of all the constituents. This technique is tedious and inaccurate when applied to self-filtering analyzers, and fortunately for users of these analyzers, sufficient experience has accumulated so that performance can be safely predicted for the more commonplace molecules. For more esoteric samples the applicability of infrared can be tested: most manufacturers can empirically sensitize and calibrate their analyzers for representative samples.

The sensitivity of an infrared analyzer is as small as 10 ppm. By special techniques, such as compressing the sample and using unusually long sample cells, higher sensitivity can be achieved (with, however, reduced selectivity). Sensitivity is limited basically by physical considerations—infrared absorption by sample molecules are just not strong enough to make much more sensitivity possible.

The outstanding feature of an infrared analyzer is its selectivity. All chemical compounds absorb infrared wavelengths, and the absorptions occur in discrete and narrow bands. Furthermore, the infrared spectrum is much wider than the ultraviolet spectrum, thus leaving room for and encompassing more absorption bands. Almost any liquid or gas sample can be analyzed by the infrared technique if the sensitivity requirement is not too high.

Refractometers

All commercially available process-stream refractometers have been designed specifically for use on liquid streams—though they have some limited applicability to gas mixtures. Broadly speaking, there are two types: one transmits a beam of light through a relatively clear (non-turbid) sample and has high sensitivity; the other, of lower sensitivity, reflects a light beam from the sample and can be used with either clear or murky solutions.

A refractometer is preferred for analyzing a binary-liquid mixture when the minimum range-of-concentration variation is not less than about 0.4 percent. Broader ranges are more easily handled. Violent temperature or pressure fluctuations of the sample produce inaccurate composition readings and require accessory equipment to stabilize these variables to maintain accuracy.

Refractometers are only useful, of course, when the changes in composition of the process stream produce a comparable change in refractive index of the solution. The correlation between refractive index and chemical composition must be unique and unambiguous, a situation that holds only for samples that behave as binary mixtures. Such simple mixtures are frequently encountered. Furthermore, multicomponent mixtures frequently behave as binary mixtures—all but one of the components have the same refractive index value, or two components vary in concentration in a complementary way, one increasing at the expense of the other while the concentration of the remaining components is constant.

The uniqueness of calibration can be checked in three ways: empirically, with a refractometer installed in the plant on a trial basis; in a laboratory, on grab samples representing the extremes normally encountered in the composition of the process stream; or with synthesized samples representing definitely-known normal and extreme compositions. Prior experience, information from the various handbooks of refractive index values, and formulas for estimating refractive index values may be applied when the stream composition and its expected variation are known.

TABLE 1—WHAT PHOTOMETRIC ANALYZERS CAN DO FOR YOUR PROCESS

• RECORD THE CONCENTRATION OF A COMPONENT OF A PROCESS STREAM

Concentration recording is valuable not only during in-plant operation but also while the process design is being optimized. The concentration of a class of compounds as well as the concentration ratio of two components can be measured and recorded.

• CONTROL THE CONCENTRATION OF ONE COMPONENT

A chemical process may be controlled by regulating the feed rate of reactants to maintain constant liquid or off-gas composition in a reactor. This technique may be extended to control a class of compounds or the ratio of two components.

• DETECT IMPURITIES OR CONTAMINANTS IN RAW MATERIALS

High-speed analyzers in many cases protect the process from catalyst poisons and other contaminants resulting from continuous feed of reactants. They work much faster than wet-chemicals testing of grab samples in a control laboratory.

• MEASURE PURITY OF PRODUCT OR RAW MATERIALS

Here the active-ingredient concentration, rather than the contaminant, is measured. Product purity affords another basis for automatic process control: a photometric analyzer controls the process of washing a solid product to remove a solvent, making sure that the washing is adequate but does not waste valuable water. The quality to be measured here could be the impurity content of the wash water, from which measurement product purity may be inferred.

• DETECT TOXIC AND FLAMMABLE VAPORS

The danger of exceeding the lower explosive limit (*LEL*) of solvent vapors or the toxicity threshold for sustained exposure to toxic vapors is eliminated when a continuous analyzer signals the approach of such conditions. And since these analyzers also accurately control the rate of air dilution, vapor concentration can be maintained at a safe fraction of the *LEL* and costly excess-air pumping and aspirating facilities avoided.

• DETERMINE THE YIELD OR DEGREE OF CONVERSION OF A PROCESS STEP

The operation of a scrubber, extractor, condenser, sparger, etc., can be optimized by means of continuously available information about the chemical composition within the reactor or in the process effluent.

• CHECK AIR AND STREAMS FOR POLLUTION BY INDUSTRIAL WASTES

The high sensitivity and selectivity of analyzers make possible the prompt detection of process upsets, condenser leaks, and other causes of pollution. Valuable products and reactants might thereby be saved.

Analyzer advantages

Photometric analyzers provide more accurate information, with less time delay and at lower cost, than traditional laboratory instruments. Plant operators and control chemists no longer need to perform frequent and routine titrations and other analyses: automatic analyzers free them for such things as complex analyses, for which automatic instruments are not yet available.

The main advantages of the photometric analyzers, then, are their versatility and their relatively small costs of purchase, operation, and maintenance. Analyzer versatility is well-known: a variety of time-tested instruments is available, and at least one can be selected for any job with a minimum of uncertainty about its performance. Of course, several other types of analyzers are preferred over photometric analyzers for certain applications, such as the electrolytic hygrometer for trace-moisture determinations and mass spectrometers and gas-chromatographic analyzers for rapid-sequence analysis of several components in a mixture. Of particular import, however, is the sustained good performance these analyzers provide, even when operated at high sensitivity. They can accurately record composition, often for month after month, rapidly and without attention or adjustment.

ULTRAVIOLET ANALYZERS

The concentration of an ultraviolet absorbing material in a mixture of nonabsorbing materials can be readily determined, because concentration is directly related to the amount of absorbed ultraviolet radiation passing through the mixture. Automatic ultraviolet analyzers for process-stream applications quantitatively examine a sample component after it has been qualitatively identified in the laboratory. The analyzers considered in this article operate in the wavelength region from about 200 to 1,200 mμ (millimicrons) which includes the ultraviolet, visible, and near infrared wavelengths. Because they encompass such a broad range of wavelengths, they usually are called photoelectric analyzers.

Figure 1 shows the basic elements of a single-beam ultraviolet analyzer. A lamp source emits ultraviolet radiation, which is transmitted through a cell (equipped with transparent windows) that contains the liquid or gas sample. A detector measures the unabsorbed radiation. Such an instrument not only indicates concentration, however; it also indicates spurious concentration changes when the source intensity varies or the voltage applied to the detector changes. Therefore, all but the most elementary applications require more refined designs, some of which employ variations of the double-beam principle to be discussed later.

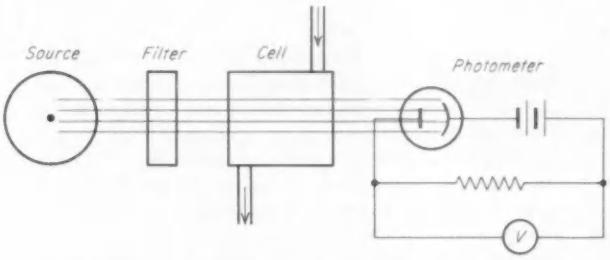


FIG. 1. Single-beam elementary ultraviolet analyzer: the sample absorbs source energy as a function of sample composition.

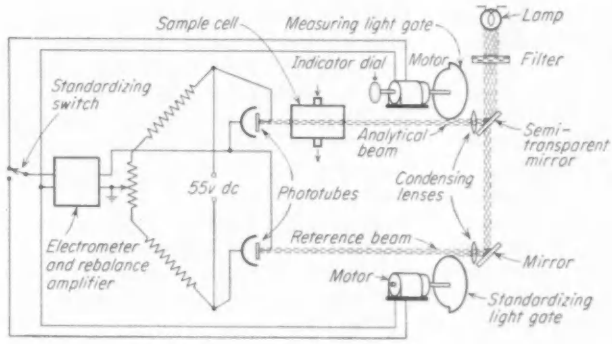


FIG. 2. A dual-beam analyzer operating on the null-balance principle provides stability, sensitivity, and accuracy.

ANALYSIS BASICS

The absorbance of a sample is directly proportional to:

- b, the length of the sample in cm
- c, the concentration of the detected component in moles/liter
- a, the absorptivity of the detected component, where absorptivity is the absorbance at a discrete wavelength when the cell length is 1 cm and the concentration is 1 mole/liter. The absorbance is:

$$A = abc \qquad (1)$$

and its measurement would give a linear reading of concentration.

However, none of the commercially available analyzers measures A. All, rather, measure the transmittance T, the ratio of energy emerging from the sample to the energy incident upon it:

$$T = Pe/Po \qquad (2)$$

The elementary analyzer described above measures only Pe and assumes that Po is constant or can be maintained so.

The relationship between absorbance and transmittance is:

$$A = \log_{10} 1/T = abc \quad \text{(Beer's Law)} \qquad (3)$$

Inherent in transmittance measurement, or in the resulting logarithmic relationship between T and c, is an error due to nonlinear calibration. However, a series expansion of Equation 3 shows that over a small absorbance range the concentration is essentially proportional to radiation absorption $(1-T)$:

$$A = (1-T) = 2.303\,abc \qquad (4)$$

Operation within this small absorbance range assures reasonable accuracy without the need to correct for calibration error in the nonlinear relationship.

In the common 0.04 absorbance range, the radiation-absorption-measuring analyzer does not depart from calibration more than 1 percent of full-scale concentration from the best-fitting straight line. This can be considered negligible. For an absorbance range as high as 0.2 the maximum fitted error is about 7 percent. At high absorbance ranges, a calibration chart at the recorder can reduce inaccuracies due to the nonlinear calibration, or the recorder can be trimmed to rectify the curvature. Linear calibrations thus can be achieved for absorbance ranges about as high as 1.0. For still broader absorbance ranges other steps must be taken to achieve linearity. One of these involves a logarithimic responding photometric circuit, but is not produced commercially.

Double-beam analyzer

A schematic diagram of a double-beam analyzer developed at du Pont's Engineering Research Laboratory for accurate and sensitive operation over even narrow concentration ranges is shown in Figure 2. Many refinements are incorporated here to afford sustained and stable operation. The two detecting phototubes are aligned in such a way with a thinly metallized semitransparent mirror that both see just the same area of the ultraviolet source. Thus, direc-

tional changes in the output of the source affect both beams in the same proportion and produce no spurious concentration readings. Gas discharge lamps (such as mercury arcs) that emit energy of a few monochromatic wavelengths are customary sources, along with combinations of optical filters that transmit one chosen wavelength suitable for the sample.

The usual circuit directly reads the ratio of the intensities falling on the two detectors and therefore measures T. The rebalance amplifier and motor null-balances the two intensities for better stability by positioning the measuring light gate to make the intensity of the analytical light beam equal the intensity of the reference beam. The position of the indicator dial attached to the light gate represents the measured concentration. A retransmitting slidewire also connected to the light gate simultaneously transmits this reading to a recording potentiometer.

Of particular significance is the not-so-obvious fact that this layout adapts to a wide variety of modifications and accessories so often essential.

Among the other available double-beam analyzers is the one developed by Phillips Petroleum Co. which employs an ingenious radiation chopping arrangement, to sensitize it only to short wavelengths in a band near 240 mμ.

ACHIEVING SELECTIVITY

Selectivity is a must in the analyzer—without it, there is no way of assuring that the instrument will respond only to concentration changes of a particular component. Spurious readings result from interferences from several sources: other sample components (perhaps unsuspected, and therefore uncompensated) that also absorb the wavelength provided in the analyzer; deposits of light-scattering mists, solids, or other fouling agents on the windows of the sample cell; and such externals as temperature-sensitive phototubes, lamp aging, dust deposits on the optics, etc. All of these can be accommodated, and for high-sensitivity operation they must be.

Like many other analyzers, the ultraviolet process-stream instruments are inferential. That is, they have no inherent power to discriminate between various molecular species. And for many applications they represent methods that are so much more

TABLE 2
TYPICAL MONOCHROMATIC WAVELENGTHS AND THE SOURCES USED TO PRODUCE THEM

WAVE LENGTH, μ	TYPE OF LAMP
228	Philips Cd UV
238, 248	Hanovia Alpine Sun Lamp
254	Low pressure Hg, such as Type G4/T4*
265, 280, 289, 297, 302	Type CH3*, high-pressure Hg
313, 334, 365, 391, 405, 436, 546, 578	Type S4*, medium pressure Hg
326, 340, 347, 361, 468, 480, 509	Type FH4* HgCd lamps or Philips Cd lamp

* These types of lamps are available from several suppliers, including General Electric, Sylvania, and Westinghouse.

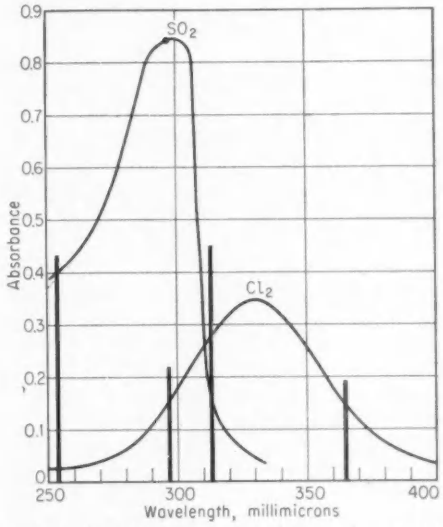


FIG. 3. Absorbance characteristics of sulfur dioxide and chlorine at a concentration of 10 percent by volume (each component) in air at 27 deg C in a 1-cm long cell.

sensitive than any previously used that it has been a major problem to find adequate means for calibrating them. These and other problems make it necessary to build safeguards into the analyzers to make sure that they will selectively read just the concentration of the desired component.

Selectivity is enhanced in a variety of ways, several of which may be used simultaneously:

- choosing wavelengths
- designing sample cells
- treating samples

Choosing wavelengths

Selecting the appropriate wavelength consistent with sample composition is basic to achieving desired response in the analyzer. Though tungsten lamps, hydrogen arcs, and other continuous (broad-band) radiation sources used with interference filters can all be used for this selection, best results are obtained with highly monochromatic radiations of the atomic spectra of gas discharge lamps. Some of these monochromatic wavelengths and their sources are listed in Table 2. Once obtained, they can be selected by optical interference filters.

For highest sensitivity, the analyzer should be operated at the wavelength where the desired component has its absorbance peak, an arrangement seldom possible except for the simplest samples. This wavelength might lead the engineer to specify an impractically thin cell; he may also find that another sample component—present in high concentration—has a strong absorptivity at the same wavelength. In nearly all applications a compromise wavelength is chosen; it might be the wavelength of a subsidiary peak of the measured component where absorptivity is less.

With luck, the compromise avoids interference by other constituents. For example, in an analyzer for

detecting acetone (or other ketones) in the presence of benzene, a suitable compromise wavelength is 313 mμ. Although more sensitivity is possible at 254 mμ, the aromatic hydrocarbons interfere there. This compromise wavelength, however is particularly beneficial if the sample is in liquid phase. With an acetone concentration of several percent, and 313 mμ or longer, a longer cell can be used to maintain equivalent absorbance. And the longer the cell, the more accurately its length can be reproduced after it has been disassembled for cleaning.

Figure 3 shows how the absorption spectra of 10 percent concentration of gaseous sulfur dioxide and chlorine occur at well-separated wavelengths. Chlorine can be analyzed near its peak at 334 mμ because the absorbance ratio of Cl_2 to SO_2 is quite large at that wavelength. But sulfur dioxide has to be analyzed at a wavelength short of its peak (265 mμ) to obtain a sensitive ratio. When the sulfur dioxide concentration is greater than that of chlorine, the chlorine measurement must be made at a longer wavelength, such as 365 mμ.

In analyzing with broad bands of radiation from a hydrogen arc or a tungsten lamp with optical filters as the source, the selected wavelength should be one at which absorptivity changes gradually. If such an analyzer is operated on the steeply-sloping side of an absorption band, nonlinearity is introduced into the calibration and the response is noisy. Nonlinearity occurs because the wavelengths of higher absorptivity are preferentially attenuated as the concentration increases; the average wavelength of the radiation band in the analyzer thus changes and the absorptivity varies with absorbance. The noise occurs in high-sensitivity applications because variation in sample temperature and pressure cause the edge of the absorption band to shift accordingly. In most cases this is less severe in the ultraviolet.

Sample cells

Another interference that frequently causes spurious concentration readings is the accumulation of dirt and dust (fouling) on sample-cell windows. Precautions against this should be taken by filtering dust and mist out of the sample and by sealing the instrument case from airborne materials.

In many cases elevated temperature can be used to minimize fouling problems. Mists in vapor samples and undissolved solids in liquid samples should be treated this way. The sample cell in the analyzer must be maintained as hot as the sample to prevent condensation. Sometimes, the vapor to be detected is soluble in the liquid phase of a mist, and a cyclone separator removing the mist would also remove a variable amount of the constituent to be determined. In such cases, complete vaporization of the sample is essential to achieving accurate analyses.

In spite of elaborate precautions, however, window fouling occurs. Most responsible are hydrocarbon samples, which produce tarry or waxy residues and aqueous samples, which yield hazy precipitates of minerals and other materials. This fouling produces a drift in the zero of the analyzer, which in most cases can be eliminated by using a one-wavelength double-beam analyzer with a sample cell in each beam. The windows foul equally, and if the response of the detectors is proportional to the ratio (not the difference) of the two intensities, then equal fouling in each beam has no effect on the analyzer reading. The analyzer is equipped with one thin compensating cell and one of normal thickness plus the thickness of the compensating cell. The same sample stream flows through both cells. The sensitivity of the analyzer is proportional to the difference in thickness of the two cells.

In some cases, a wavelength that is unique for the desired component cannot be found. A two-wavelength technique then may be used. When a single, unique wavelength where sensitivity is sufficient cannot be found, then an otherwise suitable wavelength where interference occurs is accepted, and interference is compensated by equal absorbance at the reference wavelength.

Consider again the analysis for sulfur dioxide in the presence of large amounts of chlorine and a diluent, such as air. If the amount of chlorine depicted in Figure 3 were 80 percent, determination of SO_2 concentration by measuring absorption of 297 mμ would be strongly influenced by variations in chlorine concentration and by variations in total gas pressure. The absorption spectra of these materials (Figure 3) reveal no wavelength at which sulfur dioxide alone absorbs. If the response of each phototube in a double-beam analyzer is linear in absorbance units, or if the pair of phototubes are connected to measure the ratio (not the difference) of two intensities, then the reference wavelength is selected as one where the interference effect has the same magnitude as it does at the analysis wavelength. An analyzer, Figure 4, with a cell in each beam and different wavelength in each beam is employed.

In Figure 3, the logical choice of the analysis wavelength is 297 mμ, since this is a readily available wavelength and one that is near the absorbance peak of the component to be detected. The absorbance of chlorine at this wavelength is 0.16. The reference wavelength must now be found at which

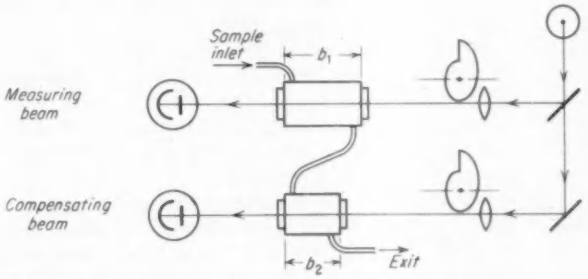


FIG. 4. Two-wavelength, two-cell analyzer for interference elimination. The construction is similar to that of Figure 2, except that each beam is of a different wavelength, due to selection of source wavelengths by interference filters.

chlorine gives the same absorbance. The best available wavelength in this case is 365 mμ, at which the absorbance is 0.15. But to eliminate the chlorine interference completely requires that the latter absorbance also be 0.16. This can be done by increasing the length of the reference cell to increase its absorbance. In this case, the reference cell should be 0.16/0.15 or 1.067 times as long as the analysis cell.

Sample treatment

Additional selectivity in analysis often can be achieved by physical or chemical treatment of the sample. Chemical treatment converts certain materials, otherwise transparent, into readily detectable materials. An example is the anthraquinone-oxygen color-forming reaction for estimating oxygen in boiler feed water and other solvents. (The reacted sample is then analyzed at visible wavelengths.) Any one of the many familiar laboratory methods of colorimetric analysis can be automated and applied to process streams. Detection of traces of phosgene for air pollution control, a good example of this technique, is accomplished with the analyzer shown in Figure 5, which monitors eight points in a plant in sequence.

But though chemical pretreatment greatly increases the versatility of the basic analyzer, it also increases its response time—from not more than a few seconds to about ½ min to 5 min or more.

Physical pretreatment methods do not always lengthen the response time this much. A variety of techniques including sparging, scrubbing, enhancement, dissolving, vaporizing, and so on, can be employed; the analyzer engineer must select the one to suit individual process requirements. Mixed vapors, for example, may be passed through a liquid in which the component to be detected is strongly soluble and the interfering material is weakly soluble. The resulting solution contains the desired component at enhanced concentration and density. The concentration of chlorine in a slurry may be determined by sparging the slurry with nitrogen or air that picks up an equilibrium chlorine content. Possibilities along these lines are almost without limit; ideas from many sciences may be employed.

SENSITIVITY CONSIDERATION

The nominal sensitivity for an ultraviolet analyzer depends on the design. Sensitivity is not always explicitly stated or readily calculable for a specific molecular species. And the applications that pose problems for the engineer are often those in which sensitivity must be lower (broader measurable concentration range or span) or higher (narrower span) than the analyzer's nominal value.

Familiarity with techniques for adjusting sensitivity span will facilitate handling the variety of problems to which analyzers can be applied. Some ideas

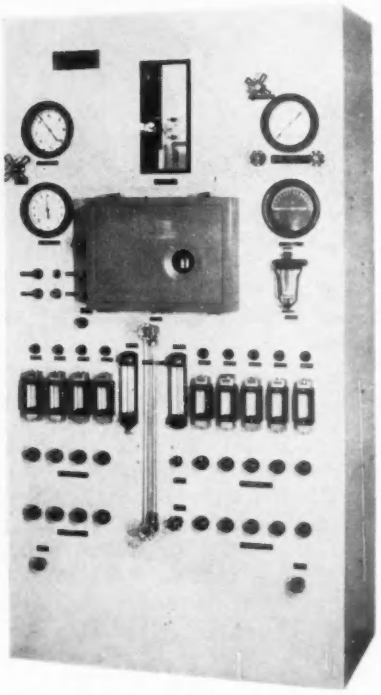


FIG. 5. Automatic photoelectric analyzer for trace detection of phosgene in air.

for increasing this span (reducing sensitivity) have been discussed in relation to selection of wavelength and cell-length. A large concentration produces the same absorbance in a thin cell as does a small concentration in a longer cell. A thinner cell is used, therefore, when a broader concentration range is required. But cell-thickness reduction can be carried to the point where the cell impedes the flow of the sample or where suspended solids plug the thin cell. Gases, with density much less than liquids, usually present no problem. For the lower-viscosity liquids, like water and most solvents, cell thickness is limited to about 0.001 in. The higher the viscosity, the greater the thickness, and at this extreme, too, passage of the sample can be impeded. But here pumps can be used to force the sample through. The minimum limiting thickness, even for very viscous liquids, still is only a few thousandths of an inch.

If a thin cell proves insufficient, there are other ways to increase the span to meet range requirements. One, frequently used but sometimes risky, is to shift the wavelength to a point of suitably weak absorptivity. High concentrations of chlorine gas can be analyzed at 436 mμ and longer wavelengths, although much higher sensitivity is available at 334 mμ. A still broader span might be obtained by using 254 mμ, but here interferences by other components get increasingly strong and numerous.

There are still more drastic measures for increasing span. In analyzing for a very strong absorber, such as furfural, the sample can be continuously and quantitatively diluted. Conventional flow controllers maintain the dilution ratio at a constant

value, but inaccuracies and high maintenance requirements make this technique a last resort.

It may be preferable to provide an electronic circuit of lower sensitivity. But here other factors begin to become important. Beer's law logarithmic curvature of the calibration, for example, gets excessive as absorption approaches 100 percent and stray light of unabsorbed wavelengths introduces still further (and sometimes variable) nonlinearity into the calibration curve.

More techniques are available for increasing than for reducing sensitivity of ultraviolet analyzers for gas analysis. Among these are the reverse of the techniques for reducing sensitivity. Extra-long cells, including those with multipass optics, as well as wavelengths of peak absorptivity, must be used. Heightened electronic sensitivity can usually be achieved readily (by increasing recorder sensitivity) when electronic noise or other instability is not present.

Any technique that increases the density of the sample component to be analyzed increases sensitivity. A gas sample may be compressed, provided it contains no condensibles such as water vapor, or provided the condensibles have been removed first. The sample also may be scrubbed in a transparent solvent—many volumes of contaminated air may be passed through one volume of water in a small packed column, and the effluent solution is then analyzed. Liquid-phase analysis is better than gas-phase analysis for an effective sensitivity increase of several-hundred fold.

The colorimetric techniques referred to in the section on selectivity may also be used to improve sensitivity. Another technique, particularly adapted to mists and air-borne solids samples, is pyrolysis (decomposition by heat). For insoluble materials and those of low-absorptivity, pyrolysis in an arc or other heated chamber may yield readily detected products. The scrubbing technique also is applicable on samples of this sort with soluble components. Low-volatility particulate compounds of mercury are readily detected by applying the pyrolysis technique and following it with an ultraviolet analyzer at the mercury resonance wave length, 254 mμ.

USES OF ULTRAVIOLET ANALYZERS

Ultraviolet analyzers are at least as useful in the chemical industry as infrared analyzers. At present, however, there are fewer of them in operation in this industry. In the petroleum industry, too, a smaller proportion of ultraviolet analyzers is employed, because the process streams here in many cases contain complex mixtures of compounds which either are quite similar in ultraviolet absorption spectra and interfere with each other or are transparent to the more readily available ultraviolet radiations. As experience with this type of instrument accumulates its uses probably will increase. At present, however, most of its applications are in the chemical, petro-

TABLE 3
MINIMUM GAS CONCENTRATIONS THAT CAN BE DETECTED BY STANDARD ULTRAVIOLET ANALYZERS

MATERIAL	Minimum Detectable, ppm		
	254 μ	313 μ	365 μ
Acetal	920	2600	...
Acetaldehyde	23	32	...
Acetone	35	83	...
Acetyl chloride	6.8	...	...
Acrylonitrile	200	...	...
Ammonia	8600	...	...
iso-Amyl alcohol	51	...	...
Aniline	0.35	...	...
Anisole	0.61	...	...
Benzaldehyde	0.041	10	64
Benzene	2.2	...	...
Benzoyl chloride	6.3	...	...
Benzyl chloride	1.3	...	...
Bromine	...	...	9.7
Bromobenzene	1.3	...	...
1, 3 Butadiene	210	...	...
iso-Butyraldehyde	20	23	...
n-Butyraldehyde	34	32	...
Carbon disulfide	170	11	3700
Carbon tetrachloride	130	1300	1300
Chlorine	1100	4.9	9.2
Chloroform	34	...	...
o-Chlorotoluene	1.4	...	...
Cyclohexane	10	...	...
Cyclohexanol	...	130	...
Cyclohexanone	64	57	...
1, 3-Cyclopentadiene	0.42	...	...
p-Cymene	1.4	...	...
Decahydronaphthalene	43	...	...
Diacetone alcohol	26	43	...
o-Dichlorobenzene	3.4	47	260
Dichlorobutene	11	...	...
Diethyl ketone	23	86	...
Di-isopropyl ketone	31	34	...
Dimethyl amine	82	...	...
Dimethyl formamide	23	...	...
Dioxane	320	...	...
Diphenyl	1.4	...	...
Diphenyl oxide	2.1	...	...
Divinyl acetylene	0.055	...	...
Ethyl benzene	4.2	...	...
Ethyl bromide	86	...	...
Ethylene bromide	18	...	...
Ethylene chlorohydrin	86	...	...
Ethylene oxide	26,000	...	...
iso-Fenchone	4.3	...	...
Formaldehyde	99	260	...
Formic acid	430	2600	...
"Freon" 21	3200	...	...
"Freon" 22	2600	...	...
Furan	1800	...	...
Furfural	0.017	5.2	...
Furfuryl alcohol	1.7	...	...
Hydrogen sulfide	130	260	...
Isoprene	1400	...	...
Mercury	0.00099	...	...
Mesityl oxide	2.3	8.6	26
Methyl butyl ketone	18	74	...
Methyl cyclohexane	1500	...	...
Methyl ethyl ketone	21	57	...
Methyl formate	290	...	...
2-Methyl-furan	43	86	1300
Methyl isobutyl ketone	21	52	...
2-Methyl-1, 3-pentadiene	6.1	...	...
4-Methyl-1, 3-pentadiene	32	...	...
Methyl vinyl pyridine	0.15	32	...
Methylene chloride	1800	...	...
Monochlorobenzene	2.3	...	...
Monoethanolamine	6.8	260	...
Naphthalene	0.078	6.0	...
Nickel carbonyl	0.063	0.52	0.60
Nitrobenzene	0.032	...	...
p-Nitrochlorobenzene	0.43	...	...
Nitrogen peroxide (NO_4)	0.57	1.3	1.8
Nitrogen peroxide (NO_2)	52	2.1	0.8
m-Nitrotoluene	0.095	...	...
Ozone	0.071	...	...
Pentachloroethane	9.2	...	...
1, cis-3-Pentadiene	180	...	...
1, trans-3-Pentadiene	26	...	...
Perchloroethylene	1.4	...	...
Phenol	1.1	...	...
Phorone	0.014	4.7	2.6
Phosgene	15	...	...
Phthalic anhydride	0.31	...	...
Piperidine	3.4	...	...
Propionic acid	8.6	...	...
Propionitrile	520	1700	...
Pyridine	0.095	...	...
Sulfur dioxide	6.3	4.1	...
Tetrachloroethane	52	...	...
Tetrachloroethylene	2.9	...	...
Toluene	1.9	...	...
m-Toluidine	0.17	...	...
n-Tributyl amine	130	...	...
Trichloroethylene	56	...	...
Trimethyl amine	20	...	...
Vinyl acetylene	110	...	...
o-Xylene	1.5	...	...
m-Xylene	1.8	...	...
p-Xylene	1.4	...	...

TABLE 4
REPRESENTATIVE ULTRAVIOLET-TRANSPARENT GASES AND VAPORS

(Absorbance less than about 0.0002 at 254 μ or longer wavelengths)

Acetic acid	Hexane
Ammonia	Hydrogen
Argon	Hydrogen chloride
Butane	Krypton
iso-Butanol	Methane
n-Butanol	Methanol
Butyl acetate	Methyl acetate
Butyric acid	Methyl "Cellosolve" acetate
n-Butyronitrile	Methyl chloride
Carbon dioxide	Neon
Carbon monoxide	Nitric oxide (NO)
"Cellosolve" (ethyl)	Nitrogen
Dimethyl sulfate	Oxygen
Ethane	Propane
Ethanol	iso-Propanol
Ethyl acetate	n-Propanol
2-Ethyl butyl acetate	Propylene
Ethyl chloride	Sulfur trioxide
Ethyl ether	Tetrahydrofuran
Ethylene	Vinyl chloride
Ethylene dichloride	Water
Ethylene glycol	Xenon
Helium	

leum, and food industries. Some are in other operations, such as paper making, mining, metal processing, painting, and pollution abatement. The samples on which the instruments are used include gases, liquids, slurries and translucent solids (the latter two accommodated by reflection-measuring techniques).

Table 3 itemizes a large number of ultraviolet detectable vapors and gases. Approximate values of sensitivity based on actual measurements (with the *MEECO* photoelectric analyzer) are given for the most common wavelengths. (If interferences are encountered at these wavelengths, other nearby wavelengths may be examined with a laboratory spectrophotometer for one suitable.) The sensitivity is given in terms of the minimum detectable amount of the material, at 27 deg C and 3-in. water-gage pressure, for the tabulated wavelengths, in an analyzer with a 19-cm cell, 0.2 absorbance range, and 1 percent sensitivity.

Some of the materials which are quite transparent, at least in the gas phase, to all the ultraviolet and visible wave lengths longer than 250 mμ are listed in Table 4. These all have absorptivity less than 0.1 l/mol —cm at 254 mμ. These pure components in most applications will not constitute interferences at ultraviolet wavelengths. Some of them absorb at slightly shorter wavelengths, such as 228 mμ.

Data on absorptivity of liquids, hence the sensitivity of ultraviolet analyzers to liquids, are much more accessible than data for gases. Data is available in the spectrophotometric curves assembled by the American Petroleum Institute; in Landolt-Bornstein "Physikalische-Chemische Tabellen"; and in many other works. The absorptivity at a specific wavelength is about the same for both gas and liquid phases of a material when the units of concentration are mass per unit volume, e.g., moles per liter. Of course, the absorption by a liquid in a 1-cm cell is several hundred times greater than the absorption by a vapor (of the same material) because the density of the liquid is higher. The absorption bands of many materials, particularly polar compounds, differ drastically in shape between liquid and gas phases. Gas-phase absorptivity can be measured directly or can be predicted with reasonable accuracy by absorptivity measurement on weak concentrations of the material in transparent, nonpolar solvents, such as hexane and iso-octance.

The applicability of an ultraviolet analyzer to a particular component can be determined either by calculation from absorptivity data or by actual test. The latter is preferred, since in most cases it must be employed anyway to arrive at the complete calibration curve for the instrument. A synthetic sample of known composition must be available, or there must be a means for independently determining the composition of a sample after it has passed through the analyzer. The latter method—using the actual plant sample—is usually preferred for determining applicability, because unsuspected interferences or difficulties in handling the sample may show up.

COMMERCIAL ANALYZERS

Only a few ultraviolet analyzers are commercially available at present. Many may prove to have wide utility and have been described in the recent technical literature. Others are custom-built for the chemical and petroleum industries.

Single-beam analyzers are used in simpler analysis problems, such as recording or sounding an alarm when color of a readily-perceptible degree appears in a normally clear and colorless liquid, or detecting relatively major changes in the concentration of one component of a simple mixture. The more complex and high-sensitivity applications in industrial plants are beyond the capability of the single-beam instruments. They generally lack required stability and automatic standardization or zero-setting to eliminate spurious readings. And none of these instruments has high enough sensitivity for gas analysis in the parts-per-million range or sufficient accuracy for automatic process control.

The range of double-beam analyzers is wider, extending to atmospheric-contaminants analysis and to process control, and they afford higher sensitivity and stability. Consequently they are more complex and costly. The available double-beam instruments differ markedly from each other in price, sensitivity, versatility, principle of operation, etc., so that the user must be familiar in detail with their capabilities and with the requirements of his process to make the proper selection.

The commercially available ultraviolet analyzers include the Beckman flow colorimeter, the Hallikainen ultraviolet colorimeter, and the Ulvir analyzer, all of which are single-beam instruments; and the Consolidated-Phillips analyzer, Kaye Spectrostat, and MEECO photoelectric analyzer, which are double-beam units. Additional ultraviolet analyzers for process streams have been disclosed in

patents and in technical journals. Some have imposing performance and have been used extensively by their developers. The generally available instruments, described below, will handle a great variety of analysis problems, including those mentioned in this article.

The Beckman instrument, basically a single-beam device, has been available to-date only with a tungsten-lamp source, making it primarily useful for visible and near-visible radiation applications. A ratio-recording version, recently developed, should prove useful in color detection, particularly where haze or turbidity interferes and presents a problem.

The Hallikainen ultraviolet colorimeter is available with either a fluorescent or mercury-vapor light source and has a single-beam operation. It is useful where either near-visible wave lengths or 254-mμ mercury-line radiation is required but high sensitivity is not. Hallikainen also manufactures a variety of simple compact analyzers in explosion-proof housings. These include inexpensive color alarms and recorders for monitoring city water supplies, 98 percent glycerin, finished kerosene, etc.

The Ulvir (Axler Associates) analyzer is a new, small, compact, single-beam instrument adaptable either for infrared or ultraviolet use. Optical interference filters permit it to achieve narrow bands of radiation. The instrument is primarily designed for broad-range operation, but no permanent plant application in ultraviolet analysis has yet been reported.

The Consolidated-Phillips analyzer was developed by the Phillips Petroleum Co. for the analysis of butadiene in hydrocarbon streams. It uses a broad band of ultraviolet wavelengths near 240 mμ, obtained from a molecular hydrogen discharge lamp. This double-beam instrument, in an explosion-proof case, will be built on a custom basis by Consolidated Electrodynamics Corp. for specific applications.

The MEECO photoelectric analyzer (Figure 6), developed in du Pont's Engineering Research Laboratory, has been extensively used in the chemical industry. Several forms are now manufactured by Manufacturers Engineering & Equipment Corp. with cells of various styles and lengths down to just a few thousandths of an inch for infrared, visible, or ultraviolet measurements at numerous discrete wave lengths. Features include pipe fittings to provide explosion-resistance through an inert-gas purge, panel mounting, multipoint sampling, automatic standardization, pneumatic or electric transmission, and recording or control. Applications have involved solvent fumes in air, solvent detection in water, control of a chlorination process, sulfur dioxide analysis on sulfuric acid plants, etc. It can handle all of the applications referred to in this article.

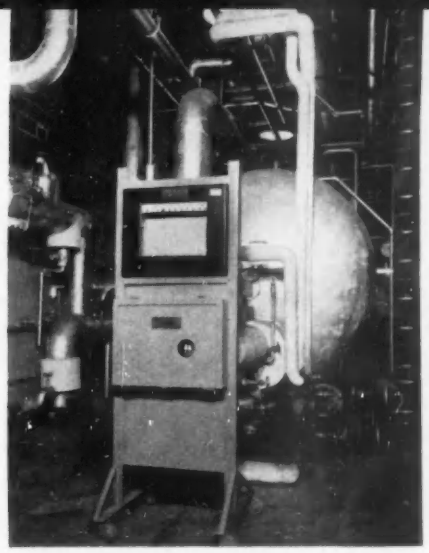


FIG. 6. MEECO analyzer, rack-mounted for portability in pilot-plant operations.

Analyzer costs

The cost of a photoelectric analyzer may be less than $400 for the simplest color alarm. More complex instruments range in price from under $2,000 to over $8,000. In addition to his outlay for the instrument, the user must also pay for the sampling pipelines, electrical conduit, recorder, instrument panel, installation, startup, spare parts, calibration, etc. These cost several hundred to several thousand dollars, depending on the complexity of the installation. The median amount for an ultraviolet application is about $3,000.

Development work for proving applicability or for devising sample-treating facilities may bring the price even higher. So may complex installations containing temperature and pressure regulators, filters, and other accessories; long runs of temperature-controlled sample lines, multipoint sampling and recorders; automatic-control features, including proportioning valves; and sample pretreatment facilities for developing a color, enhancing the concentration, etc. A single complex installation may cost as much as $30,000. A recent complete refinery installation of five infrared and three ultraviolet analyzers costs approximately $100,000.

Process stream analyzers for ultraviolet analysis are relatively complex instruments, but not more so than infrared analyzers. Maintenance, in general, can be handled by trained mechanics of the type who service potentiometer recorders and pH meters. Specification, installation, and startup should be by an experienced analyzer engineer, or an instrument engineer assisted by an analytical chemist.

Ultraviolet analyzers can effect a labor savings, though this is by no means their strongest justification. Much more important is their ability to increase yield and improve product quality. In some cases they perform a control function and make possible a new process or a new product, and here they return their cost in a very short time. Median: not much more than a year. Their future, therefore, is bright. More of them will be used as they become better known, as more field testing is successfully completed, and as more accessories and sampling system components are developed.

Servo Modulators—II

electromechanical, electronic, and semiconductor-diode units

Here are typical circuits, performance characteristics, and application data for all varieties of electromechanical, electronic, and semiconductor-diode modulators. Details are given for each representative unit that is commercially available. Next month's article will cover the remainder of the semiconductor modulator types—transistor, dielectric, thermistor, etc.—and magnetic modulators.

BASIL T. BARBER, Sperry Gyroscope Co.

The first article in this group (CtE, Aug. '57, p. 65) showed where servo modulators can be used in control systems, illustrated several typical application circuits, and tabulated the performance characteristics of all types. This article carries the modulator-selection process further by examining the various circuit configurations in detail, and noting the characteristics, application possibilities, and commercial availability of specific electromechanical, electronic, and semiconductor-diode designs. Data on representative units is given if the specific modulator type is an off-the-shelf commercial item. Next month's article will detail the other types of semiconductor and magnetic modulators and will list manufacturers and characteristics of a variety of models.

Electromechanical Modulators

Electromechanical modulators are widely used in critical-performance servo systems. Most common are the variable-reactance and variable-induction types, and choppers.

Choppers

A chopper, basically a low-noise, long-life precision vibrator, can amplify dc signals of as low as 1 microvolt, and is particularly useful where input impedance, balance, drift, and signal-to-noise ratio are critical.

Figure 1 shows the most typical application of a chopper. The input transformer, T1, isolates the dc measuring circuit from the amplifier ground. The problem of a special transformer is thus introduced but is unavoidable—most sensing elements such as thermocouples are subject to grounding. Because the modulator output is a train of square waves, the servo amplifier should incorporate some type of harmonic filter capable of attenuating all harmonics beyond the second without attenuating the amplitude or shifting the phase of the fundamental frequency. Broad-band, low-Q attenuators with a maximum rejection ratio of 20 db are usually satisfactory.

Two inputs can be conveniently compared by using the circuit of Figure 2. The ac output of the modulator is the difference of two quantities that are usually equalized by means of a standard ac servomechanism, so that the modulator also functions as an error sensitive device. Ac stabilization networks can also be cascaded between the modulator and the ac amplifier.

Choppers are widely used in critical industrial applications requiring driftless dc-ac conversion with high speed and precision. Typical of these are self-balancing potentiometers, automatic-balancing strain-gage bridge circuits, weight measuring instruments, microvoltmeters, analog-computer operational amplifiers, and nuclear instrumentation. Figure 3 shows a variety of commercially available choppers.

Variable-reactance modulators

There are several techniques for changing the value of an element of resistance, inductance, or capacitance sinusoidally so that cascading it with a dc input yields an ac output proportional to the dc input. Figure 4 shows the general configuration.

Typical variable-resistance units incorporate a carbon microphone, strain gage, or rheostat. If the variable resistance varies as

$$R_V = R_O (1 + m \cos \omega_c t)$$

then the output voltage across R_L will be

$$E_O \cong \frac{mR_O}{R_O + R_L} E_I \cos \omega_c t$$

Variable inductance modulators are not commonly used because of high distortion problems. For perfect operation, the current through the inductance must vary only with the input E_I, but this is impossible if the potential across R_L is to change.

The variable-capacitance modulator is the most practical here. Tuning forks or rotary condensers are run at a synchronous speed equivalent to the carrier frequency. If the capacitance assumes a value

$$C_V = C_O (1 + m \sin \omega_c t)$$

then the output is

$$E_O = R_L C_O m \cos \omega_c E_I \cos \omega_c t$$

These modulators are used when a very high input impedance is required, and impedances as high as 10^{12} ohms are practical. They exhibit good linearity for small element excursion (up to 0.1 percent), but practical considerations involving mechanical tolerances limit the ultimate accuracy to about 1 percent. Efficiency is low. The input is substantially free of harmonic distortion, although mechanical

CHOPPERS

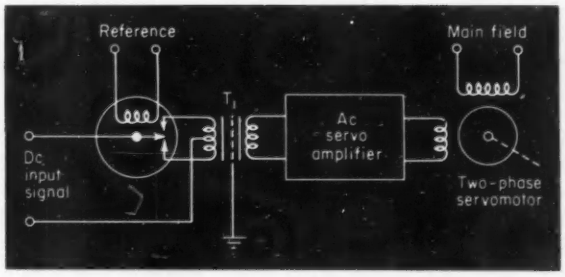


FIG. 1. Conventional application of a chopper modulator.

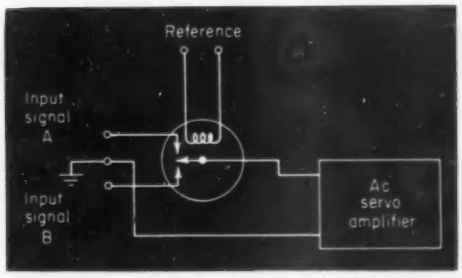


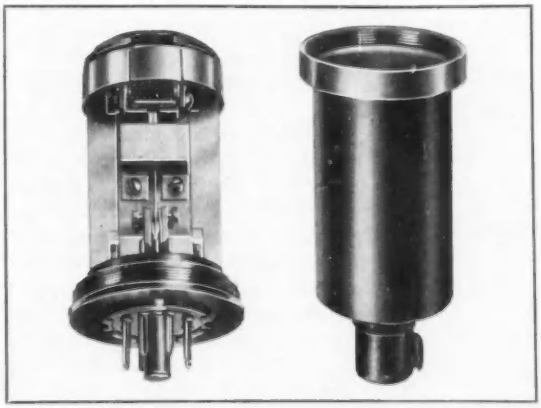
FIG. 2. Chopper as a comparator and modulator.

FIG. 3. A variety of commercially available choppers.

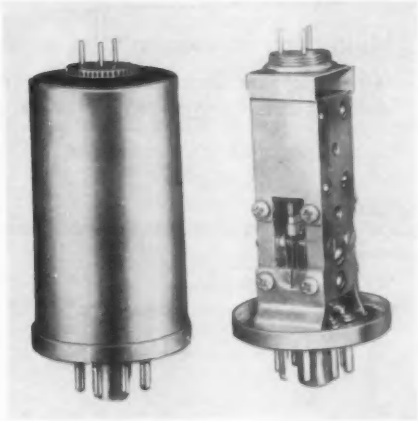
A—Airpax Products

B—Bristol

C—Minneapolis-Honeywell



D—Stevens-Arnold



E—James

asymmetries may contribute considerable intermodulation distortion. Short life and component requirements restrict the usefulness of the rotary types.

Galvanometer or induction modulators

An induction modulator is essentially a d'Arsonval movement with the moving coil positioned by the dc input signal impressed on it. Ac field coils mounted directly on the magnets produce additive flux fields in the axial direction. This in turn induces an ac voltage in the moving coil proportional to its position as determined by the dc signal. Figure 5 shows the basic circuit and a commercial model.

Induction modulator life is quite good because there are no vibrating contacts. In addition, the unit exhibits a high gain conversion, requires little filtering of the sinusoidal output, and can have a sensitivity as high as 30 microamp with a constant dc input resistance. These advantages are somewhat counterbalanced, however, by a 10-millivolt null, a linearity of about 2.5 percent, and a time constant that can be as large as 0.37 sec depending on the type of damping and the gain requirements. In null-seeking electromechanical servomechanisms, the speed of response and dead zone of the modulator can cause stability problems, but at low carrier frequencies (60 cps) with restricted bandwidth, these characteristics have given promising results. Figure 6 shows induction modulator circuitry for high and low input impedance.

Electronic Modulators

Electronic modulators have wide flexibility, high impedance levels, and high switching speed. And they are simple and low in cost. However, they exhibit a number of nonlinearities, high nulls, low dynamic ranges, and problematical drift. There are two basic classes in this group: multi-element vacuum-tube modulators, in which certain tube characteristics are modified by the modulating frequency, and vacuum-diode modulators, in which undirectional conduction is the modulating means.

Multi-element vacuum-tube modulators

This class includes grid, cathode, and plate modulators; variable μ-type modulators, keyed or cutoff tube modulators, and gate modulators. Figure 7 shows typical grid, cathode, and plate modulation schemes and a typical characteristic curve. In these circuits, the vacuum tube's transconductance, g_m, is varied from zero to a maximum value depending on the value of the input signal and reference voltages. This variation in g_m takes place along a square wave so that the output is similar to that of a mechanical chopper.

Letting the dc input, E_1, equal x_1, and the ac reference, E_2, equal x_2, and applying them both to the part of a tube's transconductance resembling a square law curve, the output, E_o, will be

$$E_O = K\,(E_1 + E_2)^2$$
$$E_O = K\,(x_1^2 + x_2^2 \sin^2 \omega\, t + 2x_1x_2 \sin \omega\, t)$$
$$E_O = K\,(x_1^2 + \tfrac{1}{2}x_2^2) - \tfrac{1}{2}Kx_2^2 \cos 2\omega t + 2Kx_1x_2 \sin \omega\, t$$

The first part of the last equation represents a dc signal that is blocked by using series capacitors or balanced out by using push-pull circuits. The second part represents harmonics that are normally filtered out by using low-pass or band-pass filters. The last part of the equation represents the desired output.

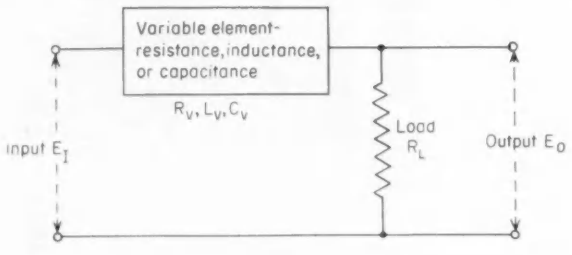
Signal-to-noise ratio, relatively low in this class of modulator, restricts it to high-signal-level applications. Other disadvantages: low efficiency (about 5 percent); nonlinear performance except for small input signals; serious drift problems resulting primarily from cathode instability; a frequent requirement for bias voltages or balancing potentiometers; sensitivity to $B+$ variations; and, on balanced types, problematical accuracy in the cancelation of undesired signals. Nevertheless, these modulators are widely used because they are flexible and inexpensive, require little power, exhibit high input impedance, have a life expectancy equivalent to that of a vacuum tube (about 10,000 hours) and have a high carrier frequency range. The last attribute makes them attractive for use in the new 1,000 cycle carrier servo systems.

Another class of electronic modulators is the cutoff type. By driving a control grid negative with respect to the cathode, a vacuum tube assumes a cutoff condition, conversely a positive voltage applied to the grid causes the tube to conduct. These two conditions can be used to modulate an incoming dc voltage in a manner similar to that of a mechanical chopper. Figure 8 shows series and parallel cutoff modulators and a typical characteristic curve.

Cutoff modulators are characterized by a high input impedance, the capacity for accepting high input levels, and relatively high efficiencies (up to 25 percent). Their output is basically a square wave.

The third class of multi-element vacuum-tube modulator is the variable-μ or variable-reactance type. The dc input feeds the grid and controls τ_p so as to form a variable-attenuation network. The output is mixed with a signal of constant magnitude and opposite phase, so that the final output represents only the actual variation of the tube. For good linearity, the

FIG. 4. Configuration of series-type variable-reactance modulator.



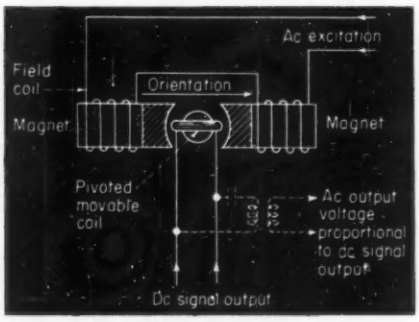


FIG. 5. Basic circuit of induction modulator and commercial version manufactured by Weston.

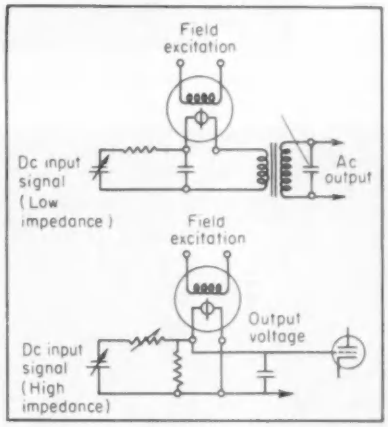


FIG. 6. Induction modulator circuitry for low and high impedance inputs.

reference voltages and bias points are selected to best fit the g_m curve of the tube. Figure 9 shows a typical circuit and performance characteristics.

The outstanding feature of a variable-μ modulator is its pure-sine-wave output. Linearities of plus or minus 1 percent can be obtained for low input level signals. The most serious disadvantage is its output response to the input level modulation—the modulators must be used in push-pull to eliminate this effect. This type of modulation adds a form of time constant that can adversely affect the dynamic performance of a complete servo system.

The last class of multi-element vacuum-tube modulator is the beam-deflection type. A beam-deflection tube has a pair of balanced deflection grids to direct the electron beam to one of the two plates and a control grid to vary the intensity of the beam. Mainly used in color television today (synchronous detectors, burst gates, etc.), they are also suited by their unique characteristics for modulator applications. Figure 10 shows a typical beam-deflector modulator. This modulator is free from space-charge coupling and reference-voltage-variation effects. Its construction best suits it for high-input signal levels, but within this limitation, outputs are good.

Vacuum-diode modulators

Prior to the advances in semiconductor diodes, the vacuum diodes yielded the highest ratio of backward to forward impedance. In addition, they exhibit high input impedance, but have high nulls and problematical drift since balance is seriously affected by heater voltage variations. Their on-off condition is usually controlled by a sinusoidal carrier—although a square-wave carrier gives greater dynamic range. Average linearity is about plus or minus 1 percent.

There are many types of diode modulators, but since they are similar to the circuits used in semiconductor-diode modulators they will be treated in detail in the following section. Figure 18 shows three vacuum-diode modulator circuits.

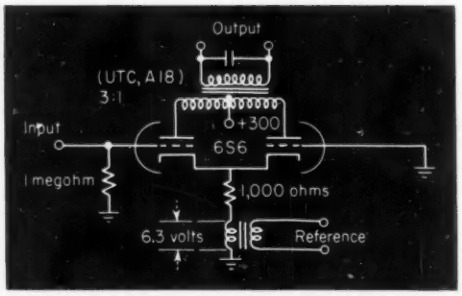
Solid-State Modulators

This class of modulators has grown in importance as a result of advances in the development of solids such as phosphors, magnetostrictive and piezo-electric materials, magnetic and ferroelectric materials, and semiconductors. In modulator applications these elements can be classified as follows: semiconductor-diodes, transistor elements, dielectrics such as voltage sensitive capacitors, nonlinear resistors such as Varistors and Thyrites, thermistors, and photoconductive elements. Only semiconductor-diode units are included in this article; the remaining types will be covered next month.

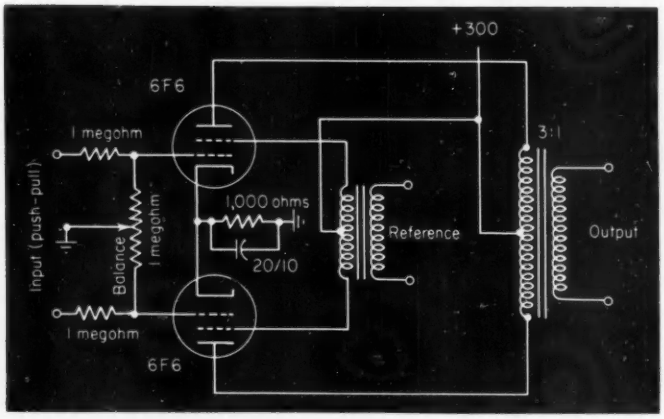
Semiconductor-diode modulators

Semiconductor-diode or rectifying-element modulators use diodes two ways, either as on-off switches

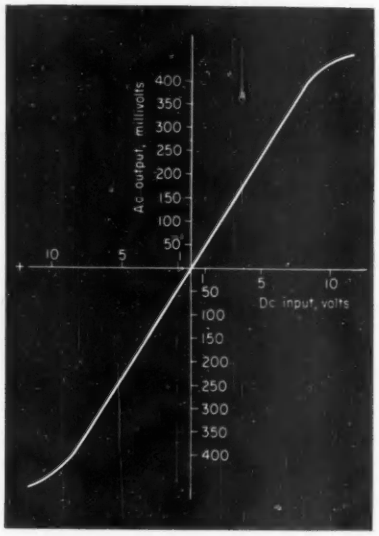
MULTI-ELEMENT VACUUM-TUBE MODULATORS



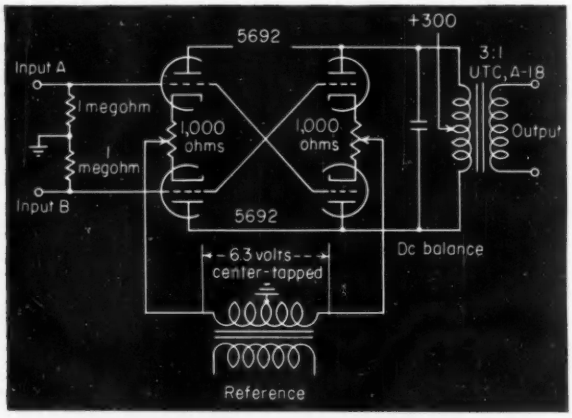
A—Cathode modulation



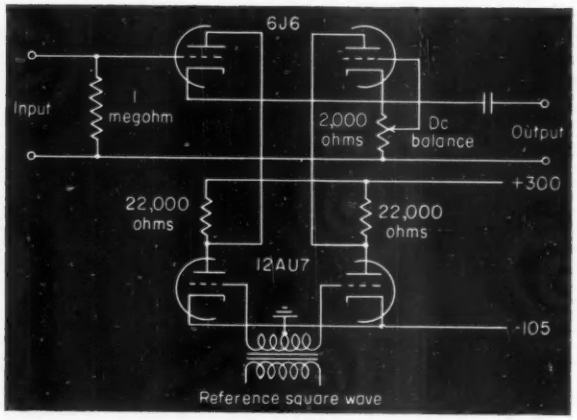
B—Secondary grid modulation



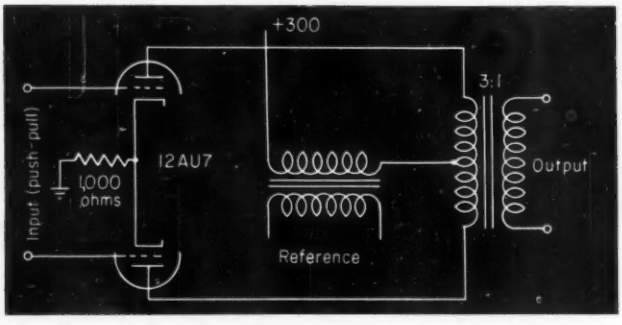
C—Typical linearity and operating level of an electronic modulator.



D—Balanced cathode modulation with two inputs.

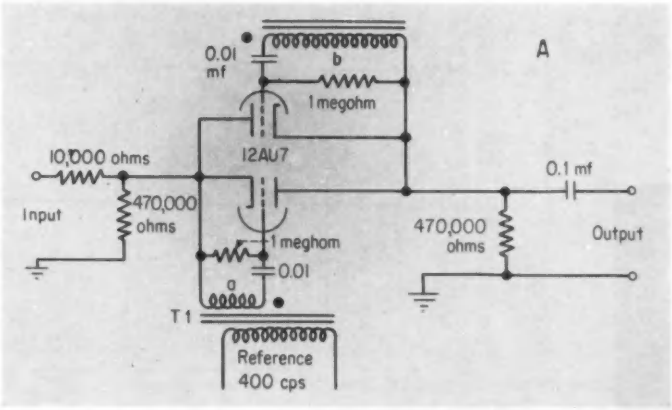


E—Plate modulation using a square-wave reference for better switching and a common cathode to minimize drift.

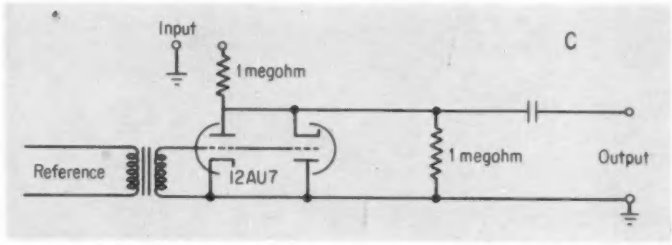


F—Plate modulation with a push-pull input.

FIG. 7. Common schemes for grid, cathode, and plate modulation.

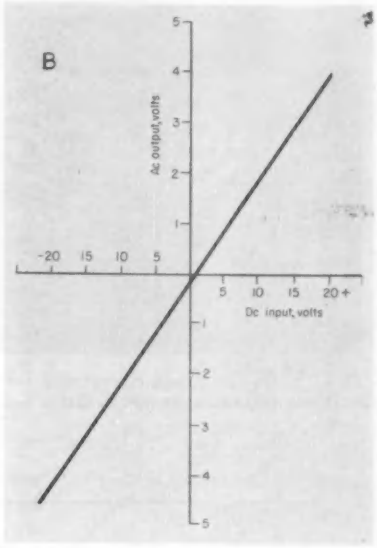


A—*Typical series-type cutoff modulator. Secondaries a and b of reference transformer T1 develop about 70 volts rms, more than adequate to turn the triodes completely on and off depending on the relative polarities of the grids and their cathodes.*



C—*Parallel-type cutoff modulator.*

FIG. 8. Cutoff-type modulators.



B—*Performance curve for modulator in A.*

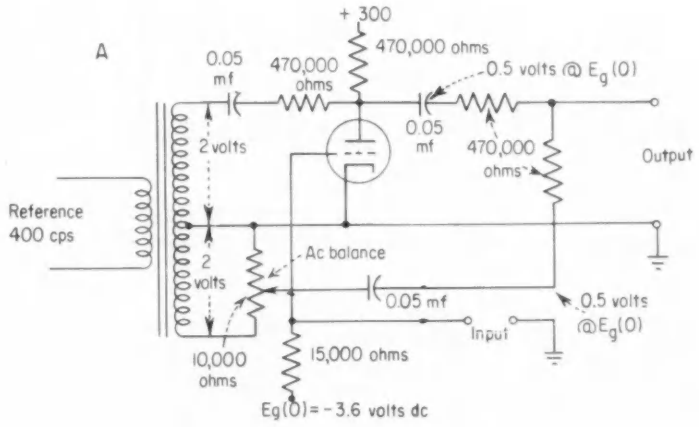
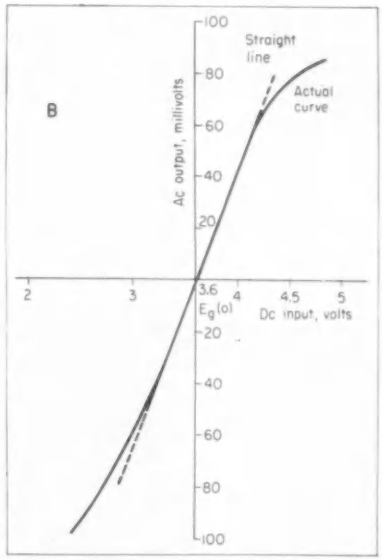


FIG. 9. Variable-μ modulator, A, and its performance curve, B.



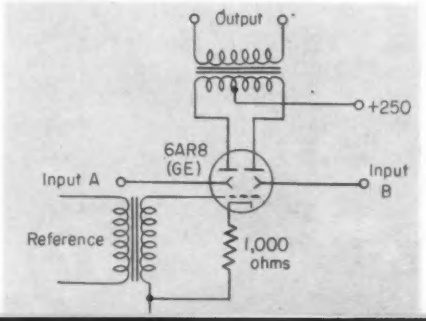


FIG. 10. Beam-deflection tube modulator.

SEMICONDUCTOR-DIODE MODULATORS

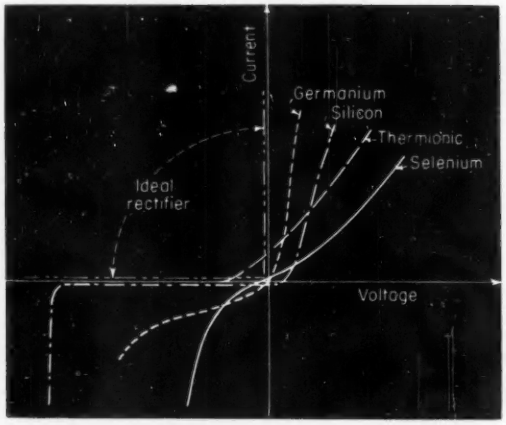
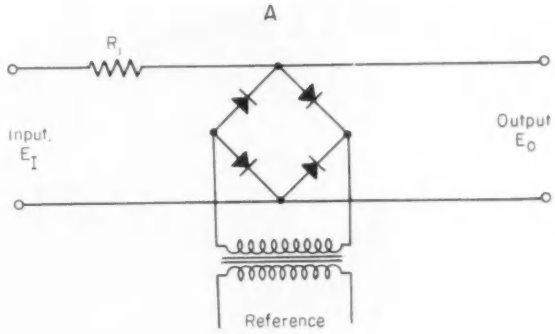


FIG. 11. Current-voltage characteristic curves of several rectifying elements compared to that of an ideal rectifier.



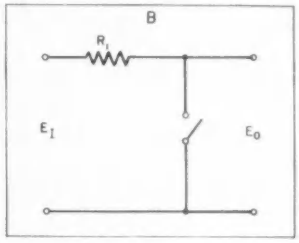
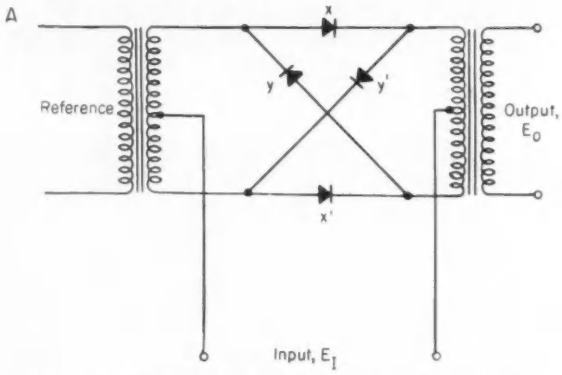


FIG. 12. Bridge or Cowan modulator in A approximates the action of a switch across the output as shown in B.



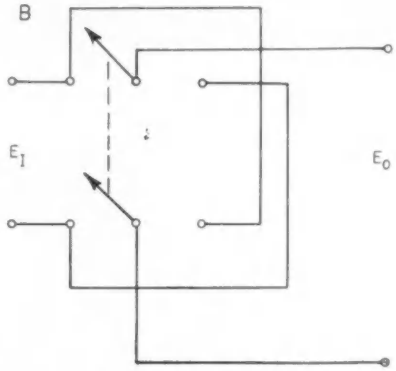
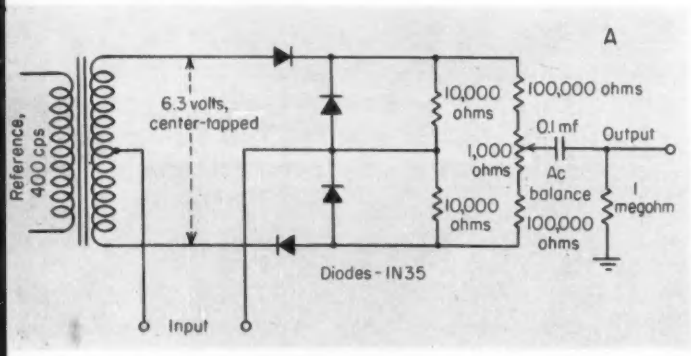


FIG. 13. As in Figure 12, the operation of the ring modulator in A is similar to that of the DPDT switch shown in B.



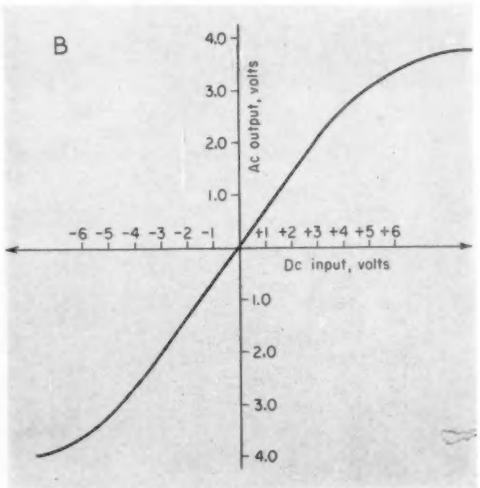
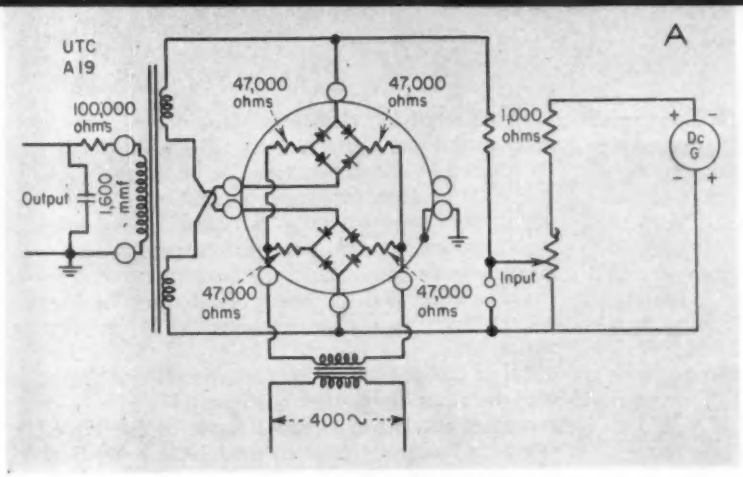


FIG. 14. Typical diamond modulator, A, and its characteristic curve, B.



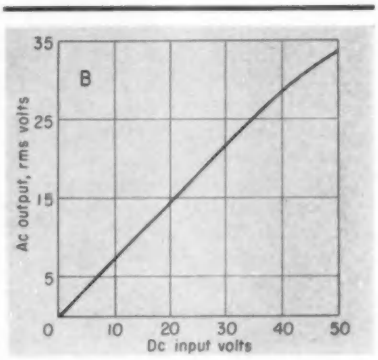


FIG. 15. Sanders Associates' full-wave bridge modulator, A, and its characteristic curve, B. Figure 17B shows this unit as a packaged plug-in component.

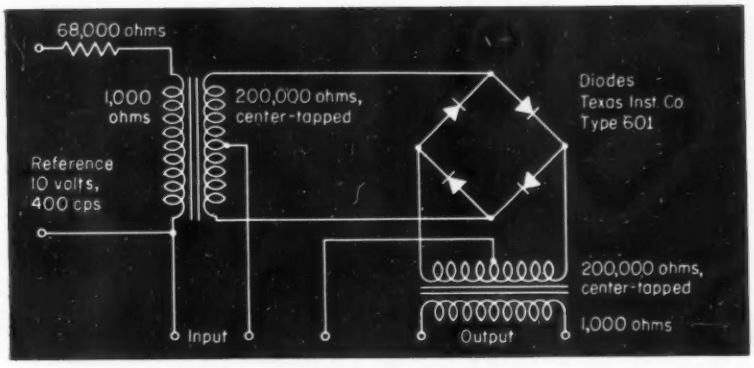
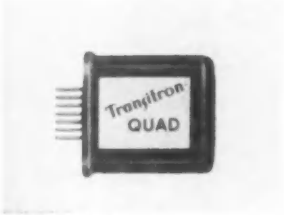


FIG. 16. High-performance silicon ring modulator.



A—Transitron

B—Sanders Associates

FIG. 17. Matched diodes packaged as plug-in units for ring, bridge, or diamond modulators.

based on the ratio of backward to forward resistance, or as nonlinear switches operating on the current-voltage characteristic of the diode. Figure 11 shows the current-voltage characteristic curves for a number of rectifying elements compared to an ideal rectifier. The residual output current that is present with zero input voltage is an obvious disadvantage of the thermionic type. When operation is centered around the null region of this curve, the residual voltage may cause considerable difficulty even if all necessary precautions are taken by using balancing and bias schemes. The disadvantage of solid-state rectifying elements is the presence of reverse current when applied voltage is reversed. The following summarizes the characteristics of the common rectifying elements used in modulators.

Copper-oxide—This element has a limited temperature range of minus 55 to plus 85 deg. C. The low blocking voltage of about 10 volts per cell maximum makes stacking necessary, thus increasing size and cost. Copper oxide is characterized by very long life, with 20-30 years of continuous operation already recorded. Short-time aging reduces the balancing problem. These rectifiers have a relatively high capacitance, but this does not affect modulator operation if the carrier frequency is below 10 kc. Copper-oxide modulators are used in room-temperature applications, where high linearity, balance, level, or null characteristics are not critical.

Selenium—This element exhibits basically the same performance as copper oxide, though rectifiers made of selenium are somewhat smaller because of a higher voltage rating (up to 70 volts per cell). Selenium is chemically active, and any abnormal penetration of moisture or vapor will cause its performance to deteriorate. Properly sealed units, however, give satisfactory results. The relatively high threshold voltage of selenium elements makes it

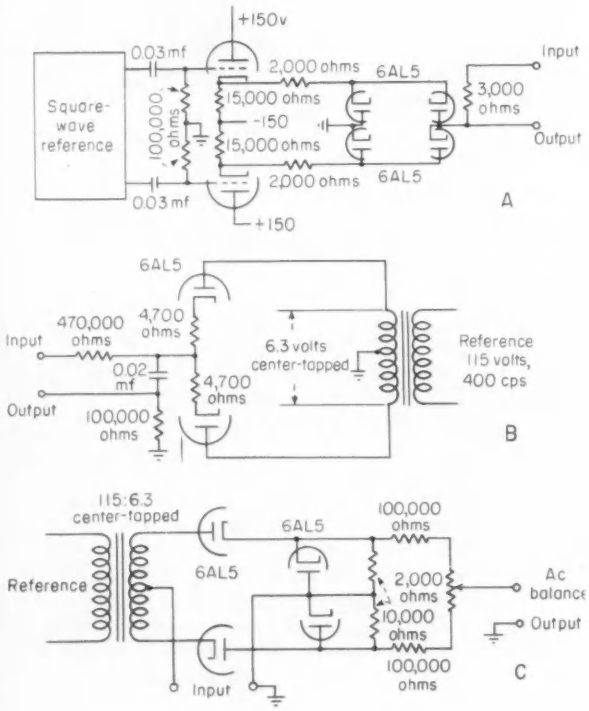
difficult to modulate signals at levels below several millivolts. Good linearity and low drift are possible.

Germanium—Limited temperature range is the main disadvantage of germanium. A ratio of 500,000:1 between backward and forward resistance makes possible a balanced-modulator design with nulls as low as 100 microvolts at room temperature. The high voltage rating per cell results in small, compact units. However, since the back resistance is relatively low, modulators using germanium diodes have inherently low input and output impedances. Modification by aging may interfere with long term stability and null constancy.

Silicon—Since silicon can withstand high temperatures, essentially the same performance can be obtained at 200 deg C as at room temperature. In addition, the extremely low saturation currents make possible ratios of back-to-forward resistance as high as 10^8, much higher than any other rectifying element. Thus, silicon diodes are ideal for high-performance modulators, especially the on-off type requiring high back resistance and good forward conductance. Other important properties of silicon diodes are their small size, negligible aging effects, and good zero stability (as low as 10^{-10} watts).

FIG. 18. Vacuum-diode modulators.

A—Typical vacuum-diode modulator using square-wave reference.
B—Simple circuit using one 6AL5 tube.
C—High-performance diamond modulator. Typical specifications: null 1 millivolt, signal-to-noise ratio 2,000:1, dynamic range 50 db, efficiency 40 percent, drift 1 microvolt per min, linearity 1 percent, and square-wave output up to 1.5 volts input.



Other rectifying elements—Many other rectifying elements, whose characteristics fall within the limits covered by the above, can also be used in diode modulators. However, their application is limited to specific cases where a particular characteristic is emphasized for optimum performance. Some of the elements are titanium dioxide, magnesium-copper sulfide, and a number of intermetallic compounds such as indium antimony and cordmium antimony.

All of the previous semiconductor diodes can be used in series or parallel configurations in a wide variety of modulator circuits. Some of the typical types are bridge (or Cowan) modulators, ring modulators, diamond modulators, full-wave bridge comparator modulators, and silicon ring modulators.

Figure 12 shows a bridge modulator. Depending on the polarity and magnitude of the reference voltage, the diodes are conducting or nonconducting. In the first approximation, the bridge can thus be assumed to act as a switch across the output, which closes during every other half-cycle of the carrier.

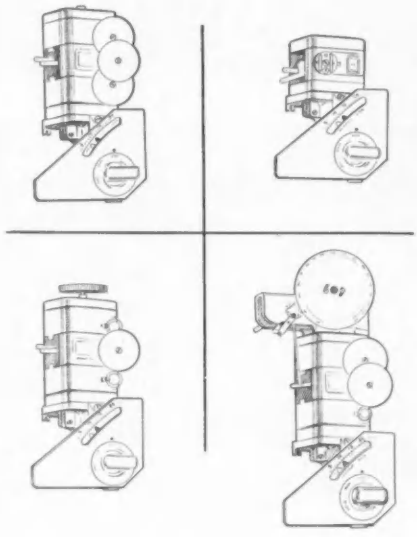
In the ring modulator circuit of Figure 13, diodes x and x′ or y and y′ conduct on each successive half-cycle, depending on the polarity and magnitude of the reference voltage. The operation is similar then to a DPDT switch operating at the carrier frequency. A typical ring modulator with matched germanium diodes gives a signal-to-noise ratio of greater than 5,000:1, a linearity of about plus or minus 1 percent, and a drift rate of 1 millivolt per hour at room temperature operation.

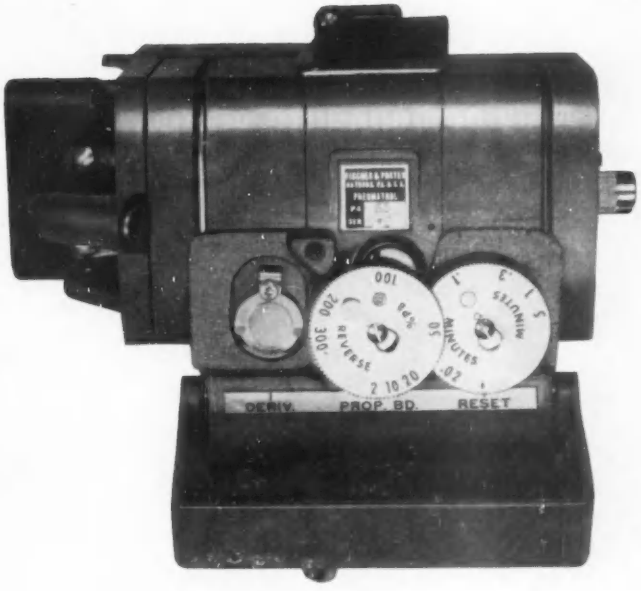
For overall performance, diamond modulators give very good results. Figure 14B shows the linearity curve for the modulator configuration of Figure 14A. Nulls of 0.5 millivolt with a signal-to-noise ratio of 8,000:1 and 1 percent linearity are feasible.

Full-wave bridge comparator modulators are basically Cowan bridge configurations in pushpull. By using matched resistors in series with the diodes, the unbalanced effects of the diodes are reduced, though at the same time the operating level of the unit increases. Figures 15A and 15B show typical circuit and performance characteristics of a commercially available unit.

By placing most of the design emphasis on the correct operating condition of the diodes, the designer can optimize a modulator to obtain the best sensitivity and stability. Figure 16 shows such a unit, designed by N. F. Moody of the Defense Research Telecommunications Establishment of Ottawa. Although it seems very similar to the standard ring types, its superior performance depends mainly on the exploitation of certain unique features of the silicon diodes, mainly the nearly perfect matching that can be attained between forward or backward resistances, or forward drops.

Figure 17 shows a variety of matched diodes, packaged as plug-in units for use in ring, bridge, or diamond modulators.





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- Even *lower* steady state air consumption—and increased amplifying relay capacity
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- Greater independence from dirty air supply
- Easily accessible external alignment adjustments
- Improved frequency response characteristics
- Greater flexibility—new "Universal" design provides 2-50% proportional action, on-off controller action, 2-100% differential gap action—in *one controller!*

Brilliant instrument design has permitted all these improvements with no change in bellows construction or motion balance principle of operation. In-case models still feature completely integrated *in-the-case* accessories, free of troublesome links or complex external members. And they can still be mounted left or right with equal ease, permitting two to a single case if desired. Of course, a complete line of plug-in models for use with miniature instruments is still available.

If you'd like to investigate the renewed P-4B controller first hand, call in the Fischer & Porter field engineer serving you . . . or write for new Catalog 53P-4000 to Fischer & Porter Co., 807 County Line Road, Hatboro, Pa. In Canada, write Fischer & Porter (Canada) Ltd., 2700 Jane Street, Toronto, Ontario.

PERFORMANCE SPECIFICATIONS • SERIES 53P—P-4B CONTROLLERS

Output pressure—*3 to 15 or 3 to 18 psig*

Set point and process pressures for field or plug-in models—*3 to 15 psig*

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Temperature limit—*225 F*

Supply pressure—*17 to 22 psig*

Zero frequency gain (Reset controller)—*approximately 300*

Derivative gain—*approximately 12*

Field mounting manifold cut-off valve—*air to open*

Steady state air consumption—*0.08 scfm*

	In Case Controllers	Plug-In And Field Mounted
On-off	53PR 4101	
"Universal" controller; 2-50% proportional, on-off, and 2-100% differential gap	53PR 4241	53PN 4240
Proportional only	53PR 4301	53PN 4300
Proportional plus fast derivative	53PR 4411	53PN 4410
Proportional plus slow derivative	53PR 4421	53PN 4420
Proportional plus fast reset	53PR 4511	53PN 4510
Proportional plus slow reset	53PR 4521	53PN 4520
Proportional plus fast derivative plus fast reset	53PR 4611	53PN 4610
Proportional plus fast derivative plus slow reset	53PR 4631	53PN 4630
Proportional plus slow derivative plus slow reset	53PR 4621	53PN 4620
Ratio—Proportional plus fast reset	53PP 4511	

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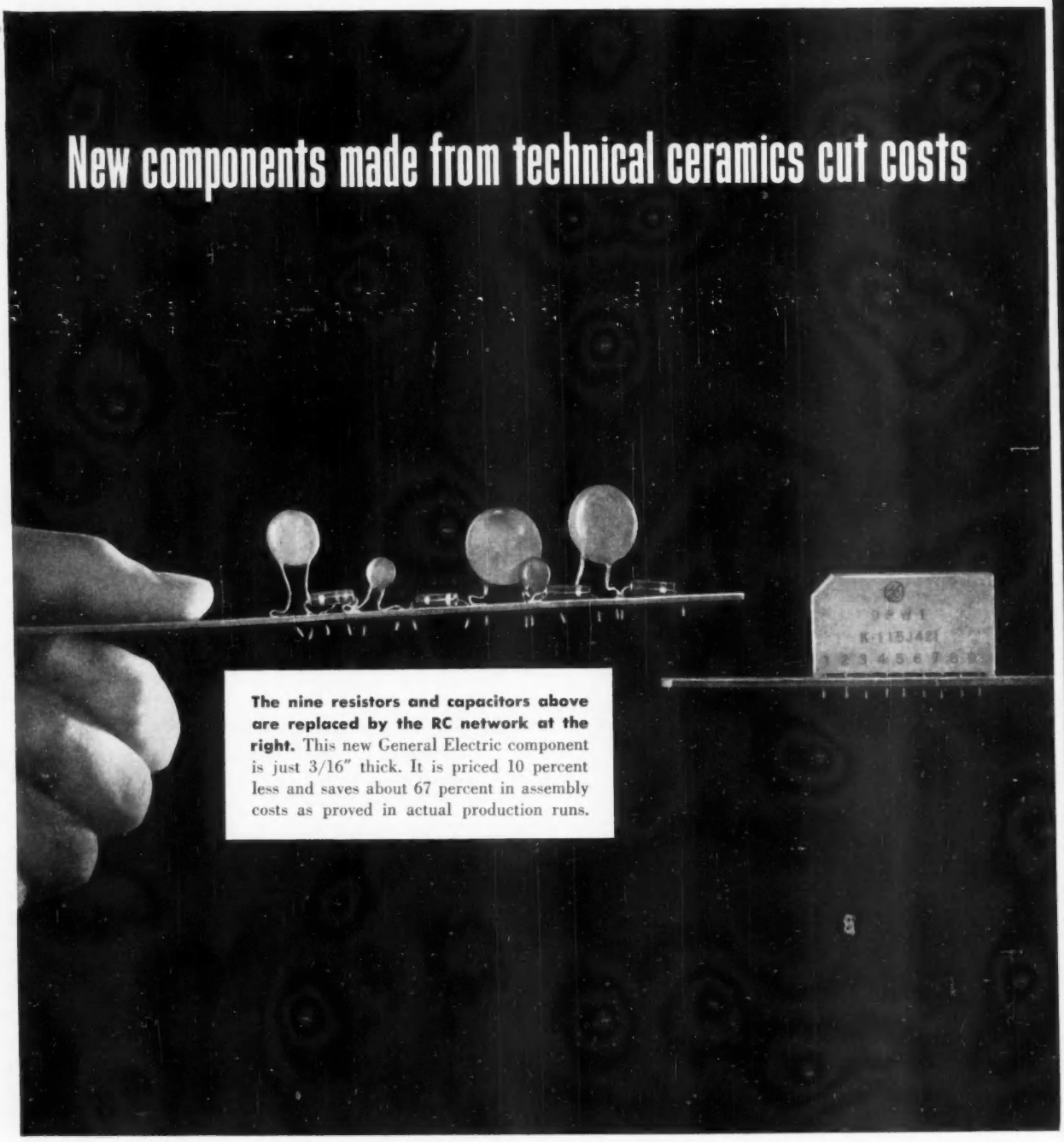
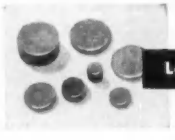
New components made from technical ceramics cut costs



The nine resistors and capacitors above are replaced by the RC network at the right. This new General Electric component is just 3/16" thick. It is priced 10 percent less and saves about 67 percent in assembly costs as proved in actual production runs.



Lead Metaniobate

A piezoelectric material recently developed by General Electric, Lead Metaniobate remains remarkably stable over the temperature range from −54°C to 265°C, an important fact in high-temperature instrumentation devices. It displays superior aging characteristics compared with other ceramic piezoelectric bodies. The high Curie temperature (570°C) allows repeated heat cycling with no effect on electrical output.

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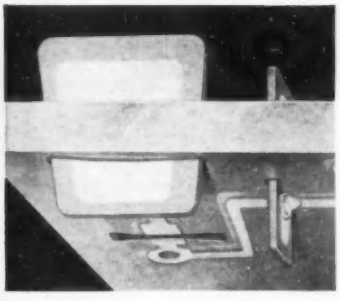
The new RC network shown at the left replaces a host of individual resistors and capacitors. The price saving can be ten percent or better. The assembly saving in print wire boards—inserting one unit instead of five or ten—averages about 67 percent. Furthermore, this small RC network results in a smaller overall assembly, at proportionate savings in board costs. Yet you are not restricted to the usual limitations due to environmental temperatures, for the new network operates at 95°C, ten degrees over the normal requirement.



Wejcap capacitors are small, flat capacitors that have no leads at all. They are merely wedged into print wire boards. Leads are an encumbrance. They get bent and broken. They are tough to align. They have to be crimped. Wejcap capacitors eliminate these problems and cost 25 percent less. Tests on Wejcap capacitors also show that four of them can be inserted in the time it takes to put in three ordinary capacitors. If only three Wejcap capacitors are applied in your volume-production chassis, you can expect to cut as much as 20 percent from your capacitor costs.

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SERVO CORPORATION OF AMERICA

Hydraulics Control Largest Tube Mill

MARVIN LARSON, E. W. Bliss Co.
W. J. BIGLEY, Tube Reducing Corp.

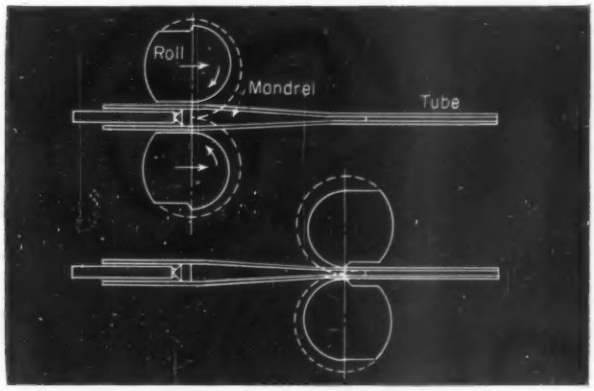


FIG. 1. Tube mill uses shaped dies and mandrel to cold-reduce tubing.

The tube reducing machine cold reduces tubing to close tolerances by the process shown in Figure 1. Rolls containing die inserts with tapered grooves are passed back and forth over the tube, working it down over a mandrel. The mandrel size controls the *I.D.* of the tube while the tapered groove in the die, slightly larger than the ingoing tube at one end and equal to the finished tube at the other, controls the *O.D.*

At one end of the stroke the tube is fed forward between the dies about ¼ inch; at the other end of stroke the tube is rotated some 60 degrees to remove ovality.

The largest tube reducing mill was built a few years ago for the Tube Reducing Corp. by E. W. Bliss Co. It can reduce 18-in.-O.D. tubing to 10 in. O.D., and is over 100 ft. long and nearly 35 ft. high.

The portion of the 18-in. Tube Mill called the saddle is the unit that contains the main rolls. It is a mass weighing approximately 150 tons, which is controllable as to speed (20 to 45 strokes per min), length of stroke (10 to 73 in.) and position of stroke (any portion of the 73 in.). The mass and speeds involved make a mechanical drive impractical. A servo-controlled hydraulic drive is used.

The power of two 700 hp induction motors is required, driving through gear reducers with massive flywheels, thus making 4000 hp available for portions of the cycle. These gear reducers drive two Series 300 Waterbury variable delivery pumps at 400 rpm, delivering 2,200 gpm at 2,750 psi on full stroke.

The servo control, more accurately described as a feedback control that is error corrected, is shown schematically in Figure 2.

The input signal is supplied by a variable-speed dc motor. The stroke rate (cpm) is directly proportional to the speed of this motor. The motor drives a scotch yoke through an adjustable crank. The linear travel of the saddle is then proportional to the length of crank. The scotch yoke rack gear is adjustable relative to the yoke, thus making it possible to put a shorter stroke in any position of the 73-in. full travel. The rack gear, through the differential, actuates a four-way line-on-line pilot valve supplying oil to the cylinder that controls the master valve. These "line-on-line" valves are designed so that a spool movement of about 0.005 inch is sufficient to change the direction of the hydraulic flow. This master valve also controls 2,000 psi oil to the pump control cylinder.

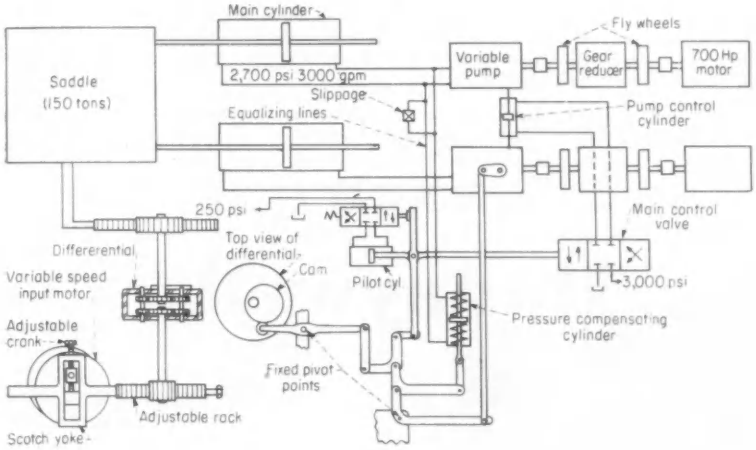
There is a mechanical feedback from the master valve to the pilot valve. It is also necessary to know the position of the pump control, the response of the saddle and the compressibility and slippage. Thus, the pressure compensating cylinder is actuated by line pressure and feeds mechanically into the pilot valve linkage, as does the linkage from the variable pump. The saddle position is fed back through an adjustable rack gear to the differential housing.

From computer results it seemed advisable to add a small amount of leakage between the main ducts to reduce the possibility of oscillation in the system. The computer also indicated that the amount of feedback, that is, the ratio of corrective action to the error, was critical—too much resulting in instability, too little in sluggish and inaccurate response.

In actual test running of the Tube Mill it was found that any looseness in the linkage would cause the saddle to oscillate. Another characteristic of this system is that the stroke is slightly longer at the same stroke settings when running slow than when running fast. This is due to a 30 deg lag in the system at high speeds.

Backlash was satisfactorily negated by the use of preloaded gearing and special, Bliss-designed, servomechanism linkage pivots.

FIG. 2. Hydraulic control system for 150-ton saddle has 4,000 hp hydraulic drive, mechanical feedback from several points.



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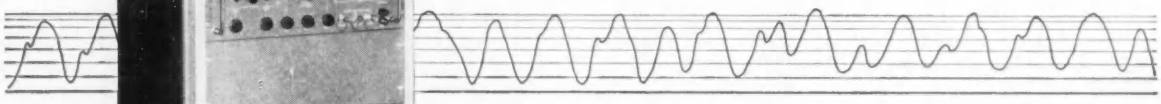

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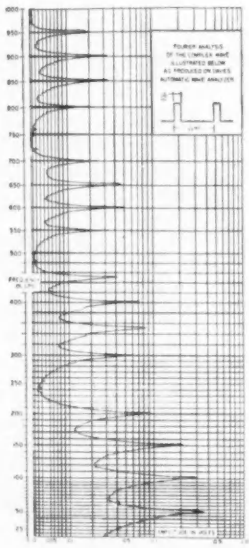

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DAVIES LABORATORIES DIVISION

Computer Demonstrates Missile Yaw

Built to demonstrate an important dynamic characteristic of missiles, this special analog computer has a couple of interesting aspects: regenerative operational amplifiers, and a simple way to modify an old ac scope to display dc signals

SAMUEL E. DORSEY
U.S. Naval Ordnance Test Station, China Lake, Calif.

An analog computer has been designed and constructed to demonstrate the yawing motion of a spinning missile. Yaw is a significant characteristic of any missile, but it is especially so of a spinning missile. It is defined as the angle between the missile's longitudinal axis and its direction of travel.

The differential equations of the yawing motion are usually solved on a general-purpose electronic differential analyzer, but an inexpensive display device was needed to familiarize new personnel with the effects of various missile parameters on yawing characteristics. Thus, a fixed-function special-purpose computer was built using parts and assemblies that could be salvaged from previous projects around the laboratory.

Spinner yaw equations

The yawing motion of a spin-stabilized missile may be described by the following differential equations:

$$\ddot{\lambda}_x = -H\dot{\lambda}_x + M\lambda_x + \nu(\lambda_y + T\lambda_y)$$
$$\ddot{\lambda}_y = -H\dot{\lambda}_y + M\lambda_y - \nu(\lambda_x + T\lambda_x)$$

where H is the damping moment, M is the overturning moment, and T is the Magnus moment (all aerodynamic coefficients), ν is the spin rate, and λ is the yaw angle. The subscripts x and y refer to the horizontal and vertical components of the yaw angle, respectively.

To study the yawing behavior of an actual missile, phototheodolite data from the Aeroballistics Laboratory is converted into rectangular coordinates by a digital computer and the actual yawing path of the missile is recorded on an analog computer plotting board. Potentiometers on the electronic differential analyzer representing the eight adjustable factors of the problem (the aerodynamic moments and spin rate, plus the initial conditions of yaw angle and angular velocity) are then manipulated until the pen on the plotting board follows a path through the points plotted from the actual yawing path. The numerical value of each of the desired coefficients is then found by multiplying the potentiometer settings by appropriate scale factors.

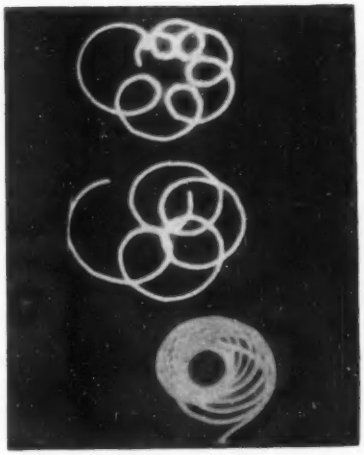


FIG. 1. Typical yaw patterns for a spin-stabilized missile.

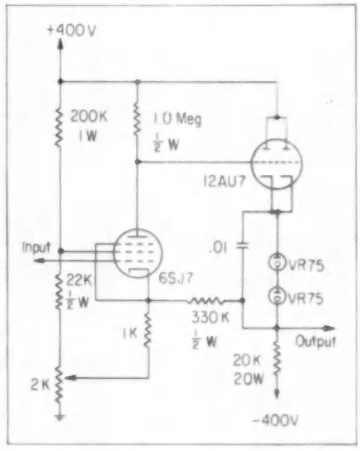
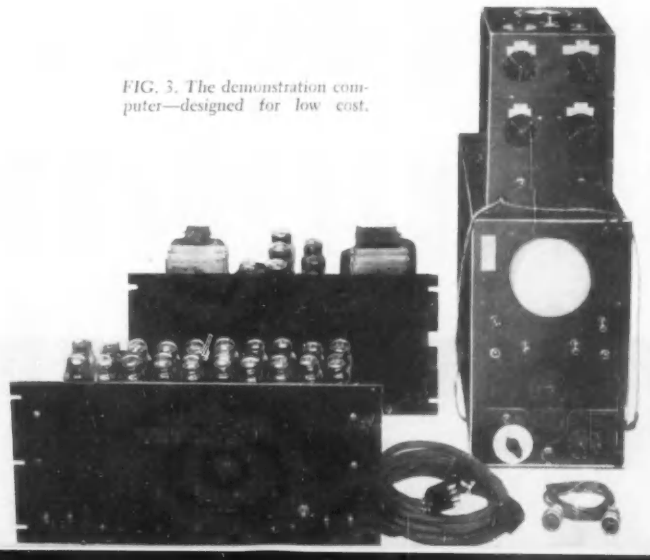


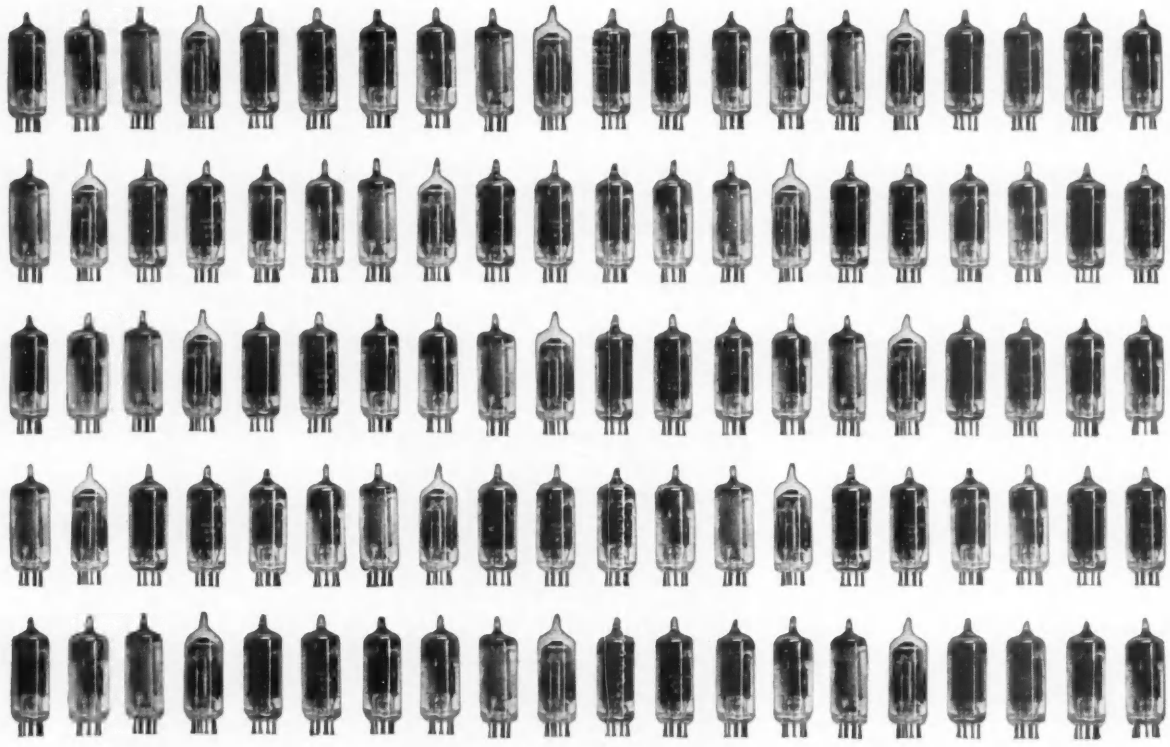
FIG. 2. Regenerative amplifier used as operational computing amplifier.

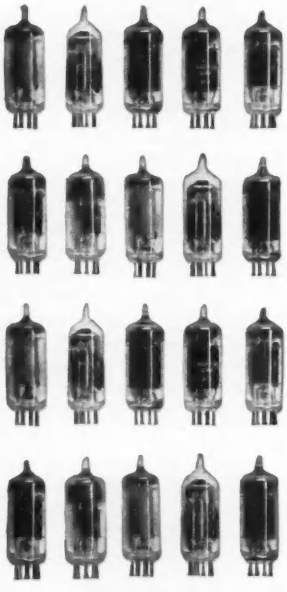
Typical yaw patterns produced on the computer are shown in Figure 1; the computer itself is in Figure 3.

The computer amplifiers are interesting because the high gain necessary for use as operation amplifiers is obtained by internal regeneration. Figure 2 is the circuit of a single amplifier (ten were originally built on a

FIG. 3. The demonstration computer—designed for low cost.







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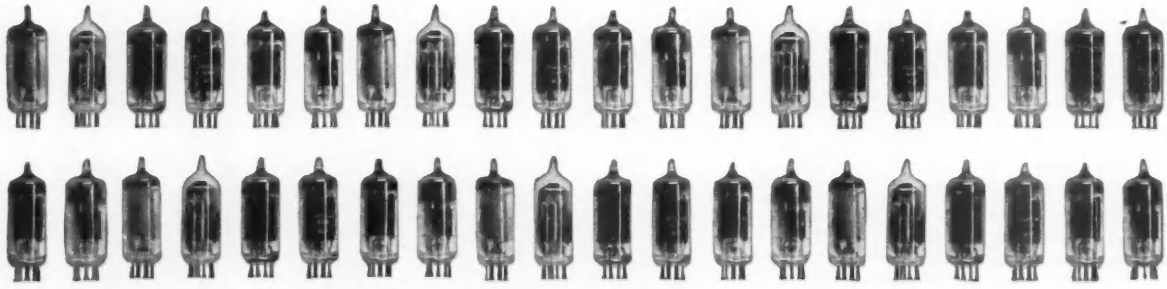


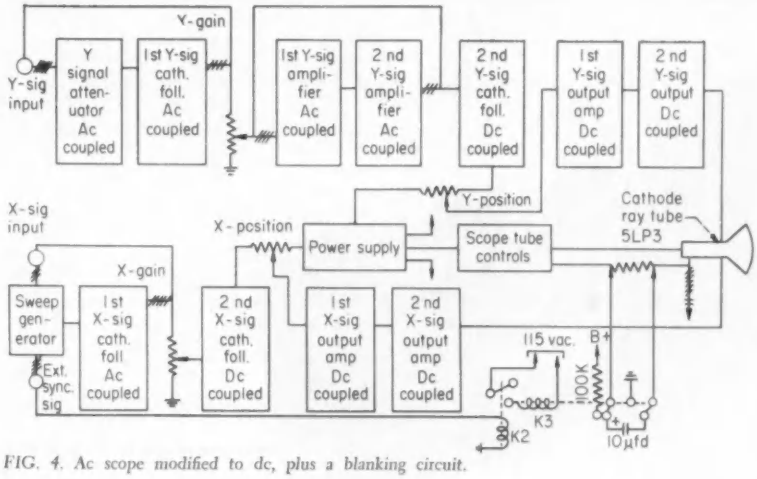


FIG. 4. Ac scope modified to dc, plus a blanking circuit.

single chassis). Note that only two stages are used, the second being a cathode follower that feeds the first stage output back to its cathode to reinforce the input grid signal. The two voltage regulator tubes merely subtract a constant 150 volts from the second stage cathode potential in order to simplify the voltage division problem of feeding back the right percentage of the change in the first stage output at the dc operation point of the first stage cathode.

The demonstration computer

All the computing components were mounted in the box shown atop the oscilloscope in Figure 3, and all interconnections were made permanently (i.e., the computer has no patchboard). Thus, the yaw demonstration computer is a fixed-function special-purpose device.

In the computer the amplifier inputs and outputs are grouped into two small 12-pin connectors, and connected to the amplifier chassis. Four of the amplifiers are used as integrators; i.e., each has a capacitor connected between its input and output within the problem box. The additions and multiplications by the constants required by the equations are carried out by the operational amplifiers in conjunction with resistors and potentiometers. Potentiometers for the same function are ganged. Amplifiers 5 and 6 are merely sign changers.

The other four amplifiers are not used directly in the problem, but perform auxiliary functions. Amplifiers 7 and 8, with inputs from the positive and negative regulated supplies of the oscilloscope, furnish the plus and minus 100 volt reference voltages for the initial-condition potentiometers. Amplifiers 9 and 10 operate relays that switch the integrator inputs from the initial-condition potentiometers to the "run" connections.

Scope modifications

The oscilloscope used was an old Dumont Model 208B, which was modified as shown in Figure 4 to be operable down to dc on both the X and Y axes. Shorting out the ac-coupled amplifier stages reduces the deflection sensitivity on each axis to about 1 in. per volt, but this can be tolerated in computer applications. The 5LP1 cathode-ray tube was replaced with a long-persistence type 5LP3.

A capacitor discharge circuit was added in the grid-cathode circuit of the oscilloscope to blank the scope face when the computer is switched from the "run" condition back to "initial conditions". This circuit has a time constant of several seconds, and is operated by a dc relay operated by amplifier 9 from the "IC-RUN" toggle switch.

Frequency Response by Sum or Difference

F. J. HUDDLESTON
Westinghouse Air-Arm Div.

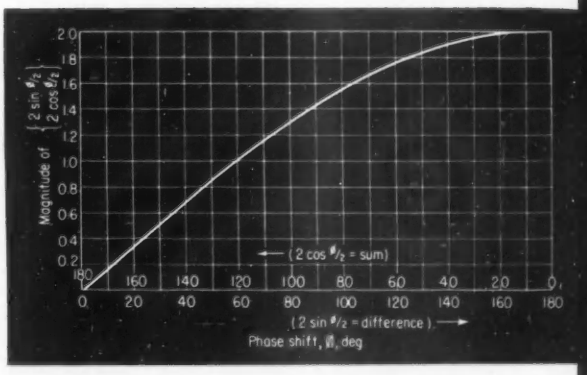


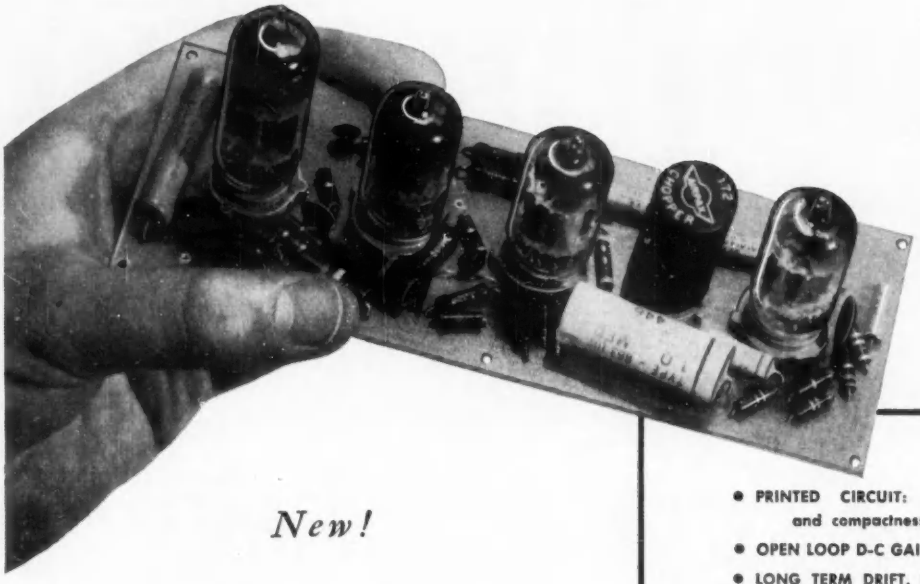
FIG. 1. Magnitude of sum or difference of input and output sine waves (of equal amplitude) vs. phase shift.

The performance of a servomechanism is usually evaluated by measuring frequency response. This requires that the relative amplitude and phase shift between the input and output signals be measured at a sufficient number of frequencies. Accurate measurement of phase shift is difficult in practice, and very time consuming. Also, when many runs are made, the results of each run are seldom available as a guide for the next run. Quick approximate methods, such as the reading of Lissajous patterns from an oscilloscope, are usually not accurate enough except for a rough guide, and do not leave a written record.

A new method will now be described which can be used with either a chart recorder or an oscilloscope. Paper charts produced by this method can be read quickly with accuracies comparable to older and slower methods, while an oscilloscope gives direct readings of magnitude and phase shift with much higher accuracies than possible from Lissajous patterns.

Sum and difference method

If the input to a servo is [1] sin ωt



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- **PRINTED CIRCUIT:** Economy, reliability and compactness.
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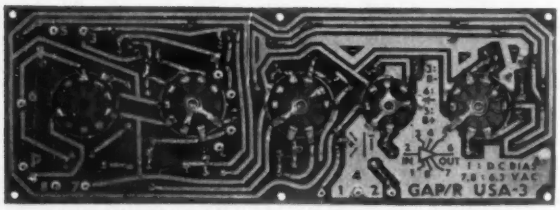
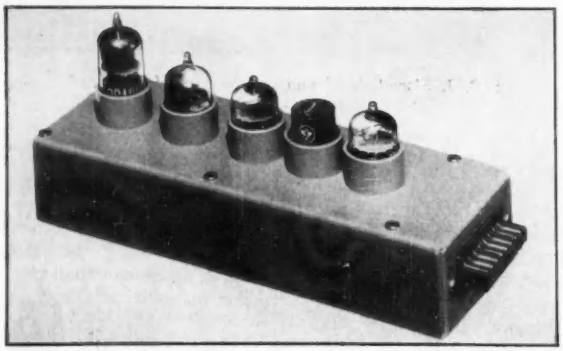
- **SIZE:** 7" x 2½" board.
- **MOUNTING:** Any convenient method.
- **PRICE:** $95.00.

PHILBRICK *PRINTED CIRCUIT* AMPLIFIER



Underside of Model USA-3 showing printed circuit, amplifier connection scheme, and connecting terminals.



Model USA-3 showing one of the several types of modular packaging available at extra cost.

Model USA-3

High performance combined with the reliability and compactness of a printed circuit design are featured in the new Philbrick Universal Stabilized Amplifier, Model USA-3. It is ideally suited for applications to instrumentation, control and analog computation. Extremely high open-loop d-c gain, wide bandwidth, low noise and wide output range are important performance characteristics of this new chopper stabilized amplifier. An interesting design feature makes this instrument safe against self-destruction, even under prolonged overload conditions or direct grounding of its output. At a price of only $95.00, it offers more performance per dollar than any other amplifier on the market today. *Write to George A. Philbrick Researches, Inc., Dept 10, for Bulletin USA-3.*

GEORGE A.
PHILBRICK
RESEARCHES, INC.
230 Congress Street, Boston 10, Massachusetts

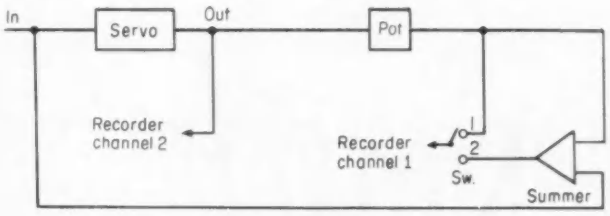


FIG. 2. Circuit for using sum or difference method with two-channel recorder.

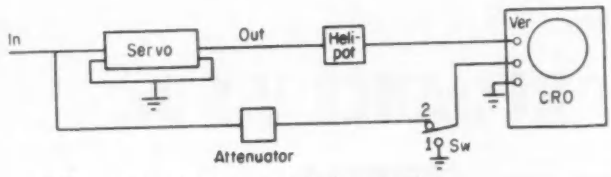


FIG. 3. Circuit for use with cathode-ray oscilloscope.

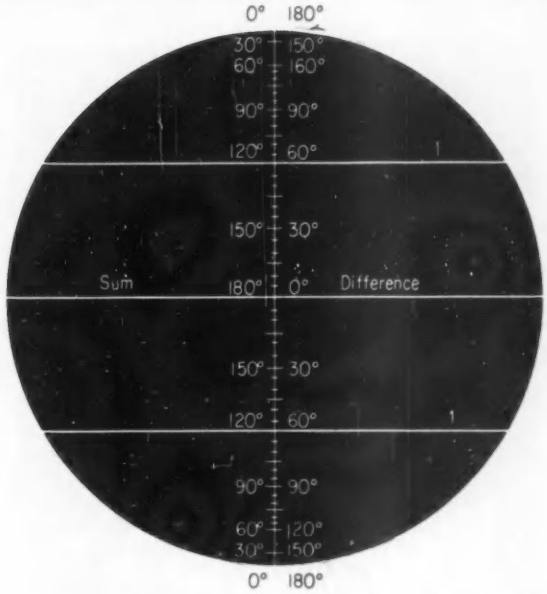


FIG. 4. Special template for oscilloscope permits direct reading of phase shift.

and the output is [1] sin $(\omega t - \phi)$, where ω is the frequency at which the phase shift of the servo is to be measured, then the difference between the input and output is a signal whose frequency is the same as the test frequency and whose magnitude is related to the phase shift of the servo by the expression 2 sin $(\phi/2)$; thus:

$$\sin \omega t - \sin (\omega t - \phi) = \left[2 \sin \frac{\phi}{2}\right]\left[\cos\left(\omega t - \frac{\phi}{2}\right)\right]$$
$$= [\text{Magnitude}][\text{Frequency}]$$

Notice that an increment of the magnitude [2 sin $\phi/2$] becomes a progressively larger amount of phase angle as ϕ approaches 180 deg. For increased accuracy when ϕ exceeds 90 deg, the input and output signals can be added instead of subtracted; thus:

$$\sin (\omega t) + \sin (\omega t - \phi) = \left[2 \cos \frac{\phi}{2}\right]\left[\sin\left(\omega t - \frac{\phi}{2}\right)\right]$$

The value of ϕ for either expression, [2 sin $(\phi/2)$] or [2 cos $(\phi/2)$], can be found from the measured magnitude by referring to Figure 1.

The sum and difference method of measuring phase angles can be used with a paper chart recorder in the manner diagrammed in Figure 2. With the switch in position 1, the pot is adjusted to make the output signal equal in magnitude to the input signal. This is usually done initially at a very low frequency so that, when making later measurements at higher frequencies, it is only necessary to adjust the pot so the recorded magnitude in position 1 is the same. When switched to position 2, the sum or difference of the input and output sine waves is recorded with a magnitude equal to [2 cos $(\phi/2)$] or [2 sin $(\phi/2)$]. Reference to Figure 1 will give the phase angle very quickly.

The second channel of a two-channel recorder can be used as shown to plot the output magnitude directly.

Figure 3 illustrates one way in which an oscilloscope can be connected to use the sum and difference method. When the switch is in position 1, the scope is reading the magnitude of the output, and the pot can be adjusted to make the output equal to the input. The reciprocal of the pot reading will indicate the relative magnitude of the output and can be read directly. When the switch is thrown to position 2, the difference signal is read on the scope face. By using a template like that of Figure 4, the phase angle can be read directly from the scope.

Accuracy

A frequency response was made on a known quadratic over the range from 0.05 cps to 10 cps, during which the phase shift varied from zero degrees to 160 deg. With reasonable care, the sum and difference method yielded results accurate within plus or minus 2 percent, using either a Brush recorder or a 4-in. oscilloscope. In the rush of actual field tests, an accuracy of plus or minus 5 percent might be expected using a paper chart recorder, or plus or minus 10 percent using an oscilloscope.

The predominant source of error is the inaccuracy in setting the magnitude of the output equal to the input signal. An error of 5 percent in this adjustment results in approximately a 5 percent error in the measurement of the phase angle.

Nonlinearities

Many servomechanisms produce a nonsinusoidal output in response to a sinusoidal input signal. Measurement of phase angle under these conditions is difficult by any method, and the accuracy of the results is always uncertain. The sum and difference method was tested on a sine wave input in comparison with a triangular wave and a square wave. The results were accurate within plus or minus 10 percent.

One of the requirements of the sum and difference method is that the input and output signals be equal in magnitude. But in a triangular output wave the magnitude of the fundamental frequency sine wave is only about $\frac{3}{4}$ the magnitude of the triangular wave. Therefore, if the peak value of the output wave is made equal in magnitude to the peak value of the input sine wave, the conditions for the method have not been met, and the calculated phase angle will be less than the actual value. Similarly, when the output tends to be a square wave the measured phase angle will be greater than the actual value.

For compensation, then, when the output tends to be triangular, add up to 10 percent to the measured value of the phase angle; and when the output wave tends to be broad, subtract up to 10 percent from the measured value. The amount of compensation depends on the amount of distortion.

New!

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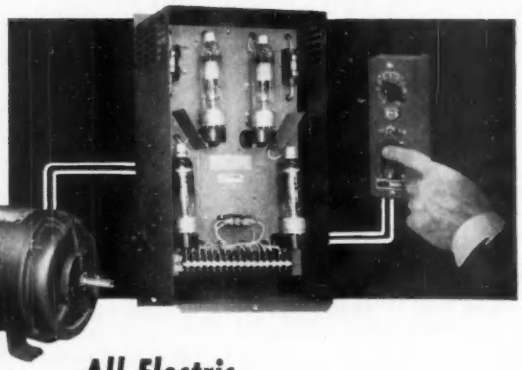

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The new V★S Jr. gives you instantaneous speed changes, even under load, without belts, pulleys, or gears. This Reliance Drive puts complete machine control at the operator's fingertips. All functions, jog, start, stop, reverse and speed changes are placed in a compact, remote control station.

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Selective Control for Gas Distribution

Flow into local distribution take-offs on natural gas transmission lines must not exceed the distribution company's "demand" contract. And, maximum pressure in the distribution system must be controlled for safety. This selective control system watches both limits.

KEITH PFRIMMER
The Bristol Co.

On natural-gas transmission lines with distribution take-offs, it is desirable to limit both maximum flow-rate to the distribution system and the maximum pressure in the system. This is an ideal application for selective-control, as the flow must be controlled during high load periods, and the pressure during low load periods.

The flow must never exceed the "maximum demand" of the contract between pipeline and distribution companies; and the pressure, measured downstream from the control valve, must never exceed the maximum safe pressure for the distribution system.

Figure 1 is a schematic diagram of such an installation at White Plains, N. Y., where natural gas from the Tennessee Gas Transmission Co.'s pipeline is metered and regulated by a selective control system into the distribution system of Consolidated Edison Co. for use in New York City. In this system, both flow and pressure are measured and one control valve is operated by selective control to prevent either flow or pressure from exceeding the predetermined maximums.

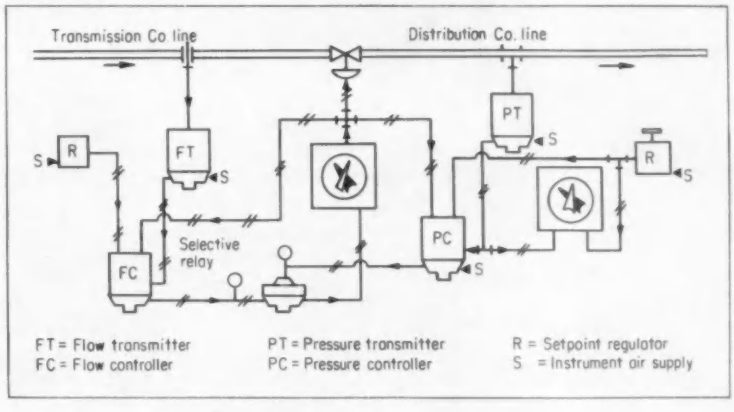
The flow is measured by an orifice and a bellows-type differential pressure transmitter upstream from the control valve, and is controlled at or below the set-point, depending on the downstream pressure. The set-point of the flow controller is thus a maximum set-point, with its value decided by the dispatcher.

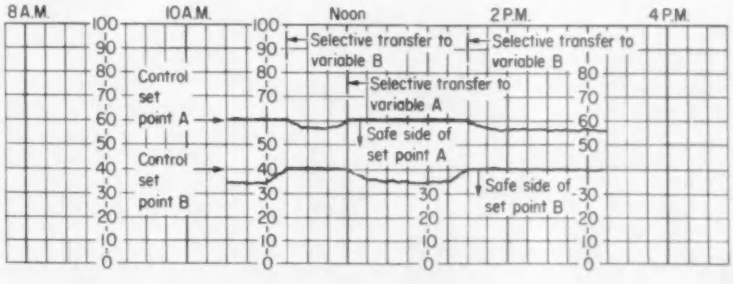
The pressure is measured by a pressure transmitter downstream from the control valve, and is controlled at or below its set-point. The maximum set-point of the pressure controller is determined by the design of the distribution system and the operating conditions decided upon by the dispatcher.

The diaphragm-operated control valve is controlled by either the pressure or flow controller and is normally closed, requiring pressure on the diaphragm top to open. The flow controller will operate the valve as long as the set-point pressure of the pressure controller is not exceeded. If the downstream pressure from the control valve attempts to exceed the maximum set-point pressure, the pressure controller through the selective relay will take over the valve operation and maintain maximum set-point pressure. This will occur, for example, when the load has decreased below that of the set-point value of the flow controller, and the dispatcher is "packing" the distribution lines. If the load increases once more, or if the set-point of the flow controller is lowered, then the flow controller will again assume control of this valve. Figure 2 is a typical chart record from the White Plains system.

Maintenance and operating personnel at the White Plains station have commented very favorably on the flexibility of the installation and its operation. Calibration checks can be carried out simply, and changes in operating conditions can be handled with a minimum of difficulty.

In an installation such as this, the units operate on filtered natural gas in place of compressed air which would require expensive auxiliary equipment.





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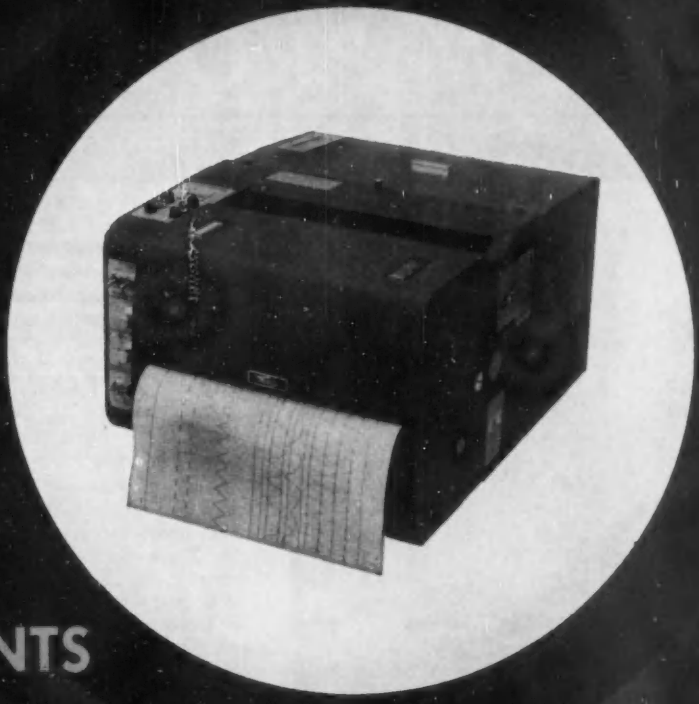
MAXIMUM NUMBER OF CHANNELS	50 Channels
RECORD WIDTH	12 inches
MAGAZINE CAPACITY	200 feet
RECORD SPEED RANGE	0.0812 to—129.9 inches per second
FREQUENCY	dc to above 3,000 cps
WRITING SPEED	Above 30,000 inches per second
OPTICAL ARM	11 inches—
POWER REQUIREMENTS	115 Volts—60 cps
TIMING LINES	0.01 and/or 0.10 second intervals
SIZE	11 1/16" x 16 13/16" x 24 1/2"
WEIGHT	130 pounds



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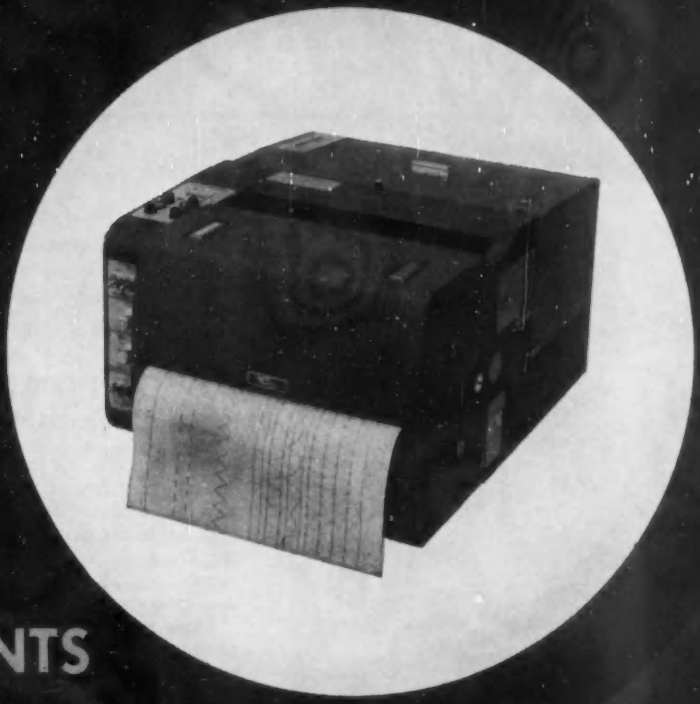

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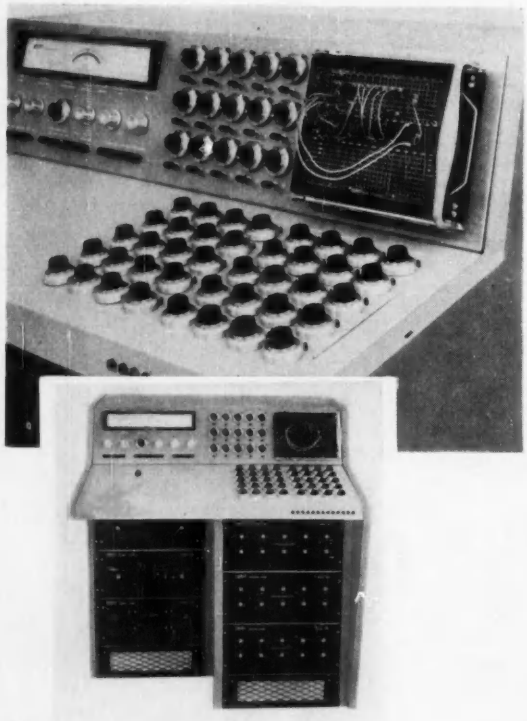


LOW-COST COMPUTER features new amplifier overload indicating system.

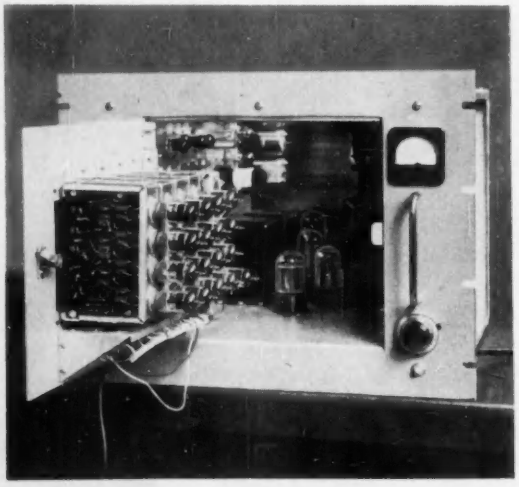
Introduced at the recent WESCON show, the new Donner Model 3100 Analog Computer fills the need for a versatile, low-cost, medium-sized computer. Standardized mass production holds the price to just over $15,000. Thirty stabilized amplifiers, 40 coefficient potentiometers, a stable reference supply, and all associated circuitry are housed within a single desk-type console.

Designed for easy expansion in the future, the unit has plug-in, dual stabilized amplifiers and plug-in potentiometer modules. Top photo left shows the well organized console as it appears to the operator. On the right side of the back panel is the Aircraft-Marine Products removable panel board. This board will not only handle the 30 amplifiers, 40 pots, six function generators, and eight channels of multiplication, but will also have 40 terminals left for other problem boards or nonlinear equipment.

Operational amplifiers have a dc gain in excess of 30 million. When connected as a unity inverter, maximum offset is below 200 mv. When operated as a unity integrator, maximum drift is less than 100 mv in 15 min. Unique overload system permits an indicator to remain energized even after the briefest of overloads. This gives the operator a complete history of amplifier performance.

Silicon diodes are used in both the power and reference supplies for better regulation and weight reduction.—Donner Scientific Co., Concord, Calif.

Circle No. 1 on reply card



ENCODER has no active contacts.

A new method for the precise and reliable conversion of current, potential, or impedance levels into digital form is now available. Known as ADIT (Analog-Digital Integrating Translator), the system has no active electrical contacts, thus eliminating a possible cause of system breakdown.

Particularly suited to applications requiring continuous converter system operation, ADIT features the following operating specs:

- Digital resolution—1 part in 10,000
- Analog resolution–cold start, 5 microvolts or 0.1 microamp; after warmup, 1 microvolt or 0.02 microamp.
- Typical ranges–1 milliamp, 50 millivolts.
- Accuracy—0.01 percent full scale on above ranges.
- Output—4-decade decimal scaler.
- Power–115 volts, 50-1600 cps, 130 watts.–Daystrom, Inc., Murray Hill, N. J.

Circle No. 2 on reply card

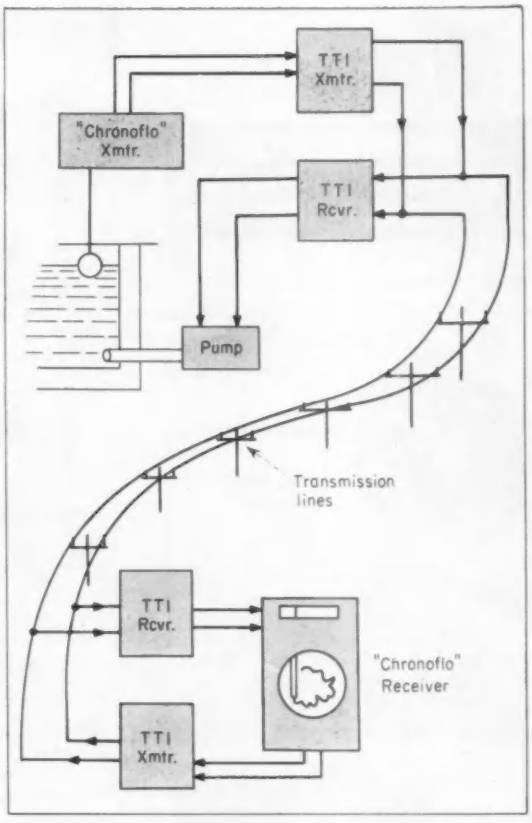
TONE-LINK fills remote control bill.

The type TT-1 tone telemetering equipment provides a frequency-division multiplexing system with up to 18 channels for remote instrumentation and/or control over a single transmission medium. Because of the design simplicity of an on-off type of operation, and because of its excellent signal-to-noise performance, the Type TT-1 equipment is very reliable. Transistor circuitry offers maximum dependability.

In operation, the system converts circuit closures of variable duration to either the presence or absence of any one of 18 audio tones of equivalent duration. These tones, ranging between 420 and 2,460 cps, are transmitted over wire, radio, or microwave facilities, and are reconverted at the distant terminal into their equivalent circuit closures. This is done by keying a tone-generating transmitter, thereby causing that tone to be amplified and transmitted, via the communications facility, to the receiving point. There it is separated from other on-off tone signals by a two-stage toroidal filter.

One obvious application of this equipment is remote level control. For example, in a municipal water system, levels can be monitored in reservoirs, standpipes, and elevated tanks, and automatically controlled simply by adding a second TT-1 auto tone circuit. The schematic, right, shows such an arrangement. A float-activated Chronoflo transmitter is fed to a TT-1 transmitter at the reservoir site. When the level falls below a predetermined value, the length of the pulses transmitted to the control station cause the pen-recorder to close auxiliary contacts in the recorder mechanism. These contacts are wired to a second TT-1 transmitter at the control center which remotely energizes a relay at the reservoir to start a pump operating. When the water has reached its proper level, indicator contacts will open and the pump will be turned off.–Warren Mfg. Co., Inc., Littleton, Mass.

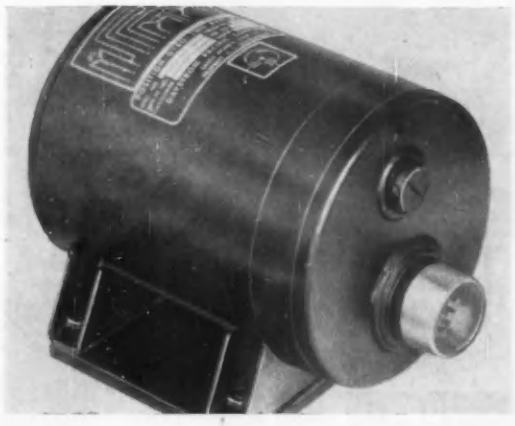
Circle No. 3 on reply card



FLOATED FREE GYRO stands 75g impact.

Pictured is the new Type F20 gyroscope, an isoelastic, fully floated free gyro having synchro pickoffs on both gimbals. Gimbal prepositioning or commanding is accomplished by means of torquers which will precess the gimbals at rates up to 2 deg per sec. The gyro drifts at a rate less than 1 deg per min in the presence of vibration loading up to 15 g directed along any axis at frequencies in the range of 10 to 2,000 cps. Scorsby drift rates of less than 0.25 deg per min are standard. It is also claimed that the instrument will withstand impact accelerations up to 75 g. A second model, the Type FC 35 (not shown), is a cageable unit and is available with either potentiometer pickoffs on both gimbals or a synchro pickoff on the outer gimbal only.–Daystrom Pacific Corp., Santa Monica, Calif.

Circle No. 4 on reply card

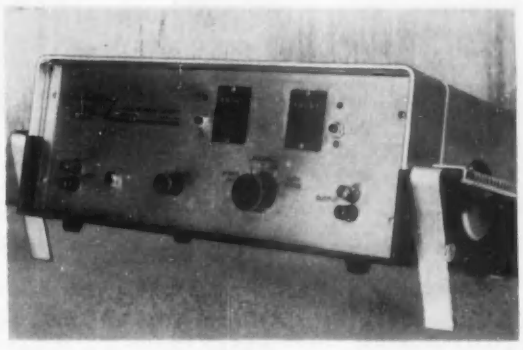


NEW READOUT speeds chromatography.

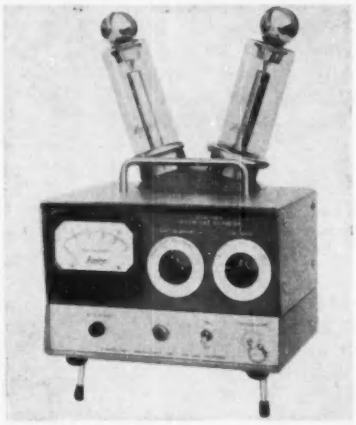
A bottleneck in the use of gas chromatographs is the time consumed in computing areas under the curves. This can often take as long as the analysis itself.

An instrument is now available that will automatically integrate these areas and present the results in digital form. Two counters are provided on the front panel for alternate use. This permits the area of one peak to be accumulated on one counter while the reading on the other is being jotted down by the operator. A selector switch also allows changing from one counter to the other. The unit contains no vacuum tubes or relays.–Southwestern Industrial Electronics, Houston, Tex.

Circle No. 5 on reply card



RESEARCH, TEST, & DEVELOPMENT



HIGH VOLTAGES

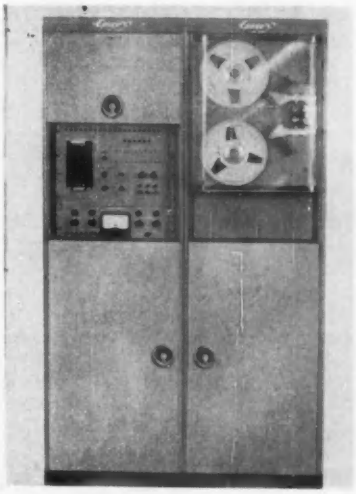
Shown is a high-voltage vacuum tube voltmeter designed to measure voltages of various waveforms, including pulses, at frequencies from 10 cps to 20 megacycles, with an accuracy of plus or minus 3 percent. Higher frequencies can be measured with a slight loss in accuracy. The linear meter scale provides full-scale readings of 2.5, 5, 10, 25, 50, and 100 kv. A vacuum capacitor voltage divider is used at each of the two inputs. Range may be doubled by installation of accessory vacuum capacitors on the high-voltage probes.—Jennings Radio Mfg. Corp., San Jose, Calif.

Circle No. 6 on reply card

PRIMARY STANDARD

Pictured is a new direct-reading, frequency-sensitive, null-indicating capacitance bridge. Designed for precise capacitance and dissipation factor measurement for two-and three-terminal capacitors, the unit has a capacitance accuracy of 0.1 percent or 0.2 $\mu\mu$f, whichever is greater, and a dissipation-factor accuracy of 2 percent or 0.0001, whichever is greater, over a range of 0.0001 to 0.1. Built as a primary standard in calibrating secondary standards, the unit contains its own 400-cps frequency regulated power supply and operates from single-phase 115 vac, 60 cps.—Daystrom, Inc., Murray Hill, N. J.

Circle No. 7 on reply card



COMPUTER ENTRY

The Model DR-704/711 Compu-Corder prepares digital test data on magnetic tape in exact computer format. It gathers asynchronous digital information from several external sources and combines them in any selected sequence, together with record numbers and manually inserted fixed data. Core storage allows input data to be accepted at peak rates of up to 40,000 12-bit words per sec. A 20-bit parallel input simultaneously accepts an average input of 1,000 words per sec. The last record number and the last test data value are indicated.—Epsco, Inc., Boston, Mass.

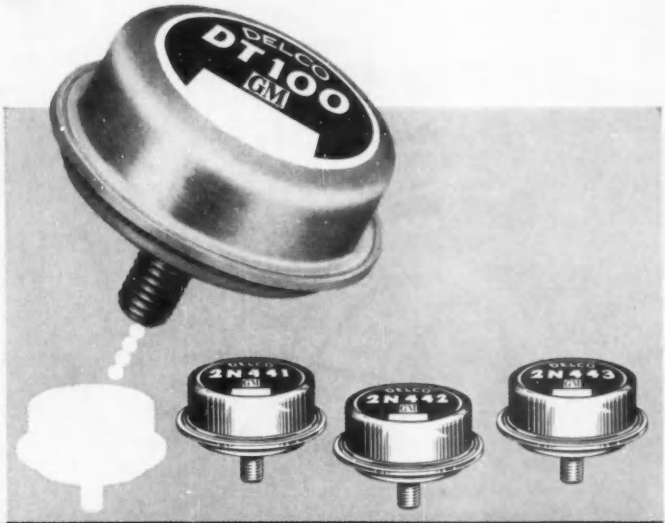
Circle No. 8 on reply card

RECTANGULAR WAVES

The Model RWG-8A rectangular-wave generator is said to be the first

DELCO HIGH POWER TRANSISTORS

Now available . . .
FOUR new types!
New LOWER prices!



Typical Characteristics at 25° C

	DT100	2N441	2N442	2N443
Maximum Collector Current	13	13	13	13 amps
Collector Voltage, Emitter Open	100	40	50	60 volts
Saturation Voltage (12 amps)	0.7	0.7	0.7	0.7 volts
Power Dissipation	55	55	55	55 watts
Thermal Gradient from Junction to Mounting Base	1.2°	1.2°	1.2°	1.2° °C/watt
Nominal Base Current I_B (V_{EC} = —2 volts, I_C = —1.2 amp.)	-19	-26	-26	-26 ma
Distortion (Class A_1, 10 watts)	5%	5%	5%	5%

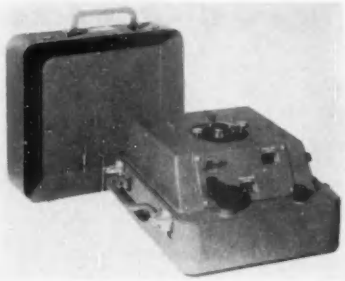
Delco Radio offers four new alloy junction germanium PNP transistors to meet an even wider range of applications. Like all of Delco Radio's High Power transistors, these are characterized by high output power, high gain and low distortion. All, too, are normalized to retain their fine performance characteristics regardless of age. Furthermore—these new types are all in volume production. Other types are available at new, lower prices. Data and application sheets and price lists are available upon request.

DELCO RADIO
Division of General Motors
Kokomo, Indiana

NEW PRODUCTS

of a line of modular instruments having self-contained power supplies for operating directly from 117-volt, 60-cycle current. Featuring output rise and fall times of 0.25 microsec, the instrument converts a sine wave or any other periodic waveform into a rectangular wave of the same frequency. A front-panel switch even permits rectangular waves to be generated at the power-line frequency. Optional features include an amplitude control and variable bias. Case dimensions are 1¾ in. by 8 in. by 8⅛ in., with a front panel that mounts in a half-width relay rack. Weight is 3 lb, 2 oz.—Elcor, Inc., McLean, Va.

Circle No. 9 on reply card



INDEX STAND

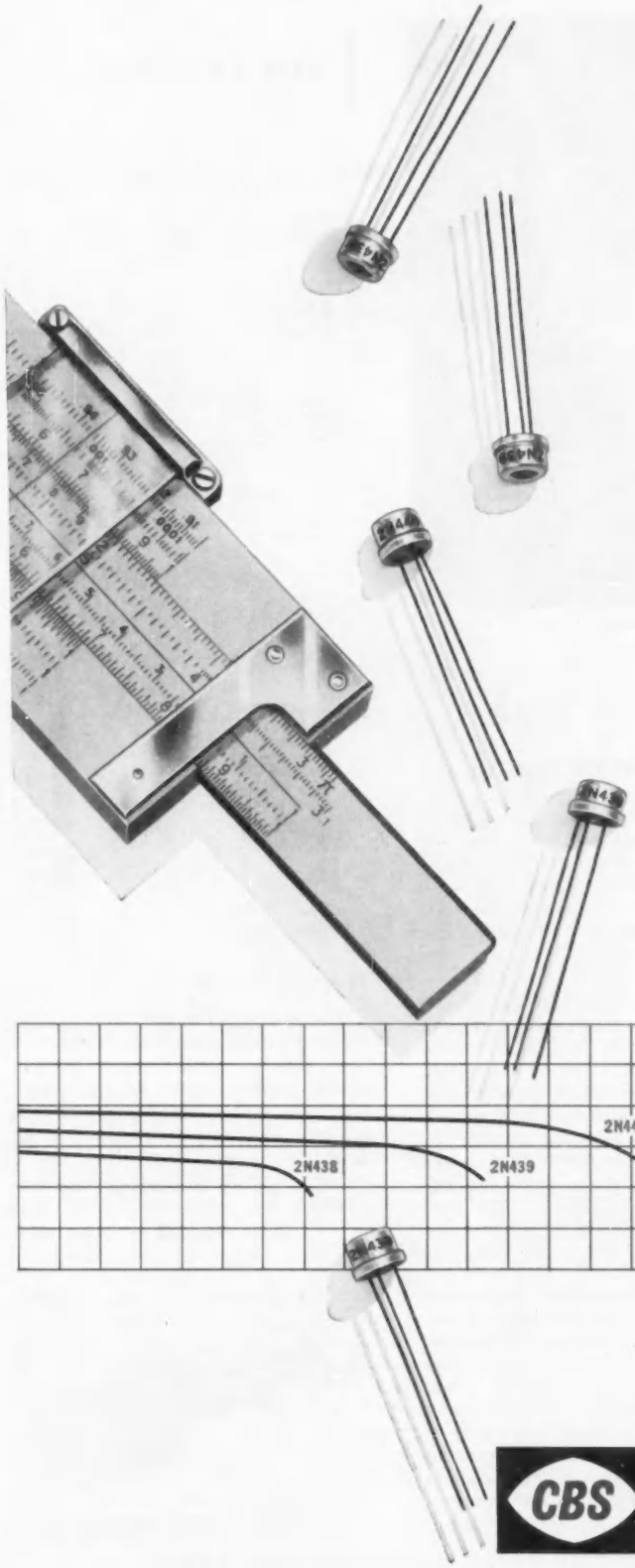
Designed to hold and accurately locate the rotor shaft of a synchro to a desired angular position with respect to the stator, this new index stand is used in conjunction with other test equipment to determine such synchro parameters as electrical error, transformation ratio, perpendicularity, and fundamental and rms null voltages. Features include interchangeable adapters for size 8, 11, 15, and 18 synchros; a micrometer head with drum dial marked off in 60-sec increments; and compliance with MIL-D85 12.—Kearfott Co., Inc., Little Falls, N. J.

Circle No. 10 on reply card

MEASUREMENT & DATA TRANSMISSION

PLASTIC VENTURI

An insert type venturi flow nozzle, fabricated of Fiberglas-reinforced polyester plastic, is now available for metering many of the corrosive



For high-speed switching

CBS HIGH-FREQUENCY TRANSISTORS

2N438
2N439
2N440

These transistors are designed for high-speed switching, control, analog and digital computer applications. All three are available in symmetrical versions, and they feature:

1. *JETEC Case* . . . employs a standard metal case (with .200 inch pin spacing) welded to achieve reliability never before approached with NPN transistors.
2. *Alloy-Junction* . . . for greater uniformity, higher voltage and current, flatter gain, and lower saturation resistance.

Note the many desirable features. Write for Bulletin E-268 giving complete data and helpful application notes.

CHECK THESE FEATURES

1. High frequency response:
   2N438 . . . . . 2.5 to 5 mc.
   2N439 . . . . . 5 to 10 mc.
   2N440 . . . . . 10 to 20 mc.
2. High operating voltage . . . . up to 30 volts.
3. High switching speed . . . . below 0.2 μsec.
4. High current amp. factor . . . . . up to 100.
5. High dissipation rating . . . . up to 100 mw.
6. Low leakage current . . . . . 3 μamps av.
7. Low base resistance . . . . . 150 ohms av.
8. Low collector capacitance . . . . . 10 μμf.

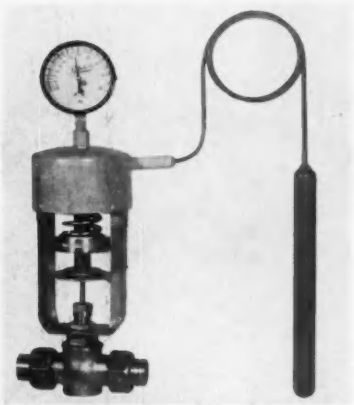
Reliable products
through Advanced-Engineering.

CBS semiconductors

CBS-HYTRON
Semiconductor Operations, Lowell, Mass.
A DIVISION OF COLUMBIA BROADCASTING SYSTEM, INC.

fluids for which metal constructions are unsuitable. Nonoxidizing acids, corrosive salts, and weak alkalis, as well as some alcohols, formaldehyde, refinery crudes, and gasoline, can be handled by this new plastic design. Line sizes range from 2 in. to 24 in. and head recovery is said to be quite high. Units are suitable for pressures to 150 psig and temperatures to 250 deg F. Features include an uncalibrated accuracy within plus or minus 1 percent of the actual flow rate, and a wide pH range.—Builders-Providence, Inc., Providence, R. I.

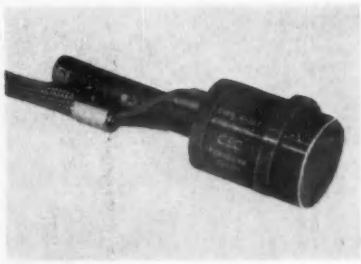
Circle No. 11 on reply card



PLASTIC COATED BULB

Designed exclusively for use in metal finishing operations, this new temperature regulator has a resistant plastic coating over its bulb and capillary. Called the No. PA-2, it is available in seven valve sizes from ¼ in. to 1½ in. Several bulb sizes are also available.—Robertshaw-Fulton Controls Co., Knoxville, Tenn.

Circle No. 12 on reply card



USES 4-ARM BRIDGE

New Type 4-317 pressure pickup is available in nine pressure ranges from 100 to 5,000 psi and can be operated

How to judge a new brand of magnetic tape

"Ampex Instrumentation Tape" bows in with facts and figures

PREMIUM QUALITY FOR SLIGHT EXTRA COST

Ampex Instrumentation Tape is a superior quality sold at slightly higher price than regular instrumentation grades. For this difference it offers a number of special advantages. Each individual reel is tested for freedom from dropouts. Uniformity from reel to reel is maintained to ±0.5 db. Within the reel, it is ±0.25 db. All the types we offer are compatible to each other and require no special bias settings. These are specifications we invite you to test for yourself.

Ampex tape can soon be ordered with precision reels. These greatly improve tape guidance and provide uniform, distortion-free tape wrap. A center plastic strip grips the tape to start.

TWO QUALITIES YOU CAN EASILY TEST

An oxide surface of exceptional smoothness distinguishes Ampex Instrumentation Tape from others. It is achieved by the Ferro-Sheen process. There are no small surface projections to rub off and accumulate oxide on heads and guides. The microscopic flatness also achieves better tape-to-head contact eliminating "noisy" variations in signal strength. Also, Ampex tape is made with a binder of exceptional adhesive strength. Try to strip the oxide off a sample of Ampex tape. Then compare it with others.

Whether you are a believer in heredity or environment, here is a mighty offspring to watch. Ampex Instrumentation Tape shares a distinguished family name with Ampex's Tape Recorders. It inherits a wealth of experience. It is growing in a fertile environment of research, testing, and process improvement.

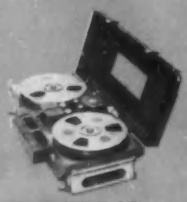
For many years each new Ampex Tape recorder has been a significant advancement in the state of the art. But in making these forward steps, Ampex's engineers repeatedly have come face to face with need for improvements in tape as well. Ampex is now sharing research and knowledge with Orradio Industries to set new standard in tape excellence. Orradio is originator of the Ferro-Sheen process – also is the largest manufacturer dedicated exclusively to magnetic tapes.

The completeness and accuracy of specifications that have always distinguished Ampex recorders are extended to magnetic tape too. The new Ampex magnetic-tape brochure clearly differentiates the kinds of tapes we offer and gives relevant specifications, features and tape-testing techniques. May we send you a copy?

MAGNETIC TAPE APPLICATIONS BY AMPEX

ONE OF A SERIES

Series FR-100



Series 800 Mobile and Airborne

Model FR-200 Digital

Series FL-100 Loop Recorders

Series FR-1100

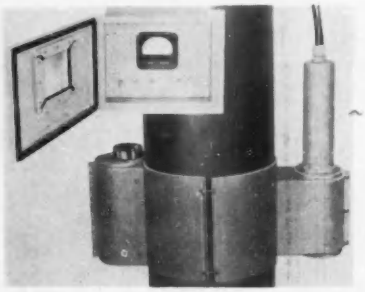
INSTRUMENTATION DIVISION
AMPEX CORPORATION
FIRST IN MAGNETIC TAPE INSTRUMENTATION
934 CHARTER STREET · REDWOOD CITY, CALIFORNIA

District offices serving all areas of the United States and Canada; Foreign Representatives in countries around the world.

NEW PRODUCTS

continuously at 5 volts maximum input over a temperature range of minus 350 to plus 600 deg F, with allowable transients up to 750 deg F. Linearity and hysteresis deviations combined are less than 1.5 percent of full-range output. Unbounded strain gages connected in a four-arm bridge comprise the sensing elements of this variable-resistance-type transducer. Just $\frac{3}{8}$ in. in diam and $\frac{3}{4}$ in. long, the unit weighs 30 grams.—Consolidated Electrodynamics Corp., Pasadena, Calif.

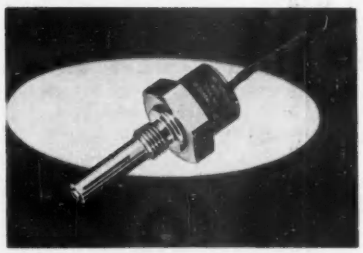
Circle No. 13 on reply card



DENSITY GAGE

Called the Model LSG, this new standardized radioactivity density gage will measure or control process variables by measuring the density, specific gravity, or percent solids of the process material. Installed on a 10-in. diam pipe, the instrument will cover a span of 0.2 with a precision of plus or minus 0.004. Because all measuring components are externally mounted, operation of the unit cannot be adversely affected by conditions of high or low temperature, pressure, viscosity, abrasion, or corrosion. Power supply voltage is 110 volts, 60 cycles.—The Ohmart Corp., Cincinnati, O.

Circle No. 14 on reply card



MEASURES TO 800 DEG F

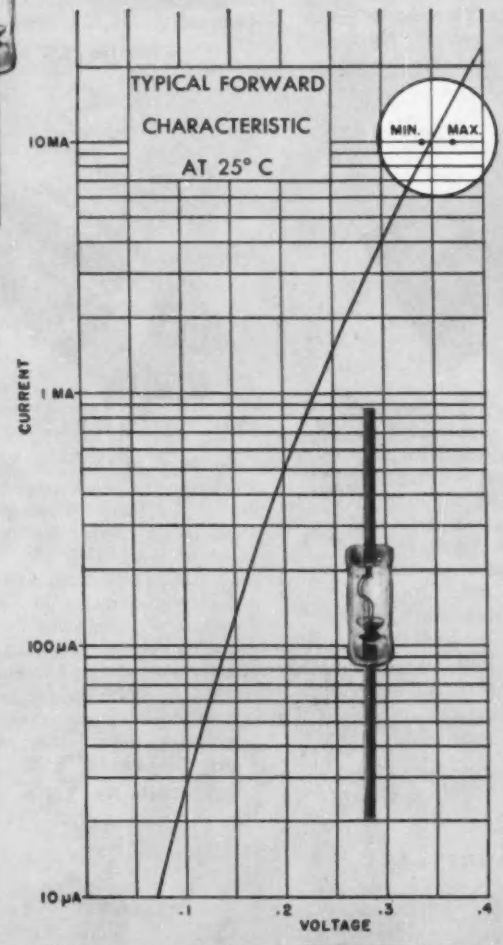
Here is a highly sensitive, variable-resistance temperature probe with a range of minus 350 to plus 800 deg F. Standard models have a resistance of 200 ohms at room temperature. Higher

for circuits requiring utmost voltage economy

GOLD BONDED

Radio Receptor Germanium Diodes

10MA forward current with a maximum loss of only .37 volts!



DR 385	DR 434	DR 435

This extremely low controlled forward voltage drop combined with fast transient response makes these diodes ideal for transistorized circuits, computers and other applications where conservation of power is of prime importance.

Characteristics at 25° C

	DR 385	DR 434	DR 435
Forward voltage drop @ 10MA			
Minimum	0.34V	0.34V	0.34V
Maximum	0.37V	0.37V	0.37V
Maximum reverse current at --10V	10UA	10UA	10UA
Peak inverse voltage	60V	40V	30V

Maximum ratings at 25° C

Maximum inverse operating voltage	50V	30V	20V
Continuous DC forward current	100MA	100MA	100MA
Surge current for 1 second	500MA	500MA	500MA
Average power dissipation	80MW	80MW	80MW
Derating above 25° C	10MW/10°C	10MW/10°C	10MW/10°C

Available now in production quantities for immediate delivery

For further information on these, or any other RRco. diode type, write today to Section

RADIO & ELECTRONIC PRODUCTS SINCE 1922

Semiconductor Division

RADIO RECEPTOR COMPANY, INC.

Subsidiary of General Instrument Corporation

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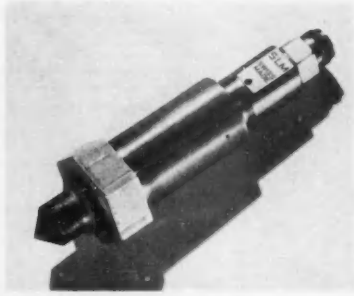
Radio Receptor Products for Industry and Government: Selenium Rectifiers • Germanium Diodes Thermatron Dielectric Heating Generators & Presses • Communications, Radar & Navigation Equipment

NEW PRODUCTS

values are available and are dependent only on the size of the immersion unit. Designed to resist abrasion and environmental stresses in air or fluids, the instruments are AN threaded for easy insertion into tapped holes. Tested to withstand pressures considerably higher than 3,000 psi, the probes are suitable for applications such as measuring jet engine exhaust temperatures, etc. All probes have a nominal temperature coefficient of resistance of 0.003 ohm per ohm-deg C. Repeatability is within 0.5 percent.—Giannini & Co., Inc., Pasadena, Calif.

Circle No. 15 on reply card



FLIP TO CALIBRATE

Calibration of this new SLM quartz accelerometer requires just a simple flip of the hand. Turning it upside down in the earth's gravity field generates a signal of 2 g's. This static calibration feature eliminates the uncertainty in vibration amplitude measurements. In addition, the unit features fast response, high accuracy, and extreme ruggedness. The model shown has a 0 to 4,000 cps frequency range and will operate continuously at 500 deg F.—Kistler Instrument Corp., North Tonawanda, N. Y.

Circle No. 16 on reply card

FOR HIGH PRESSURE

Designated the Auburn HP 10, this new liquid-level control electrode is rated for pressures to 10,000 psi and temperatures to 700 deg F. Originally developed for removing water from helium gas, the device should find a number of laboratory and chemical

ASCO literature simplifies choice of electromagnetic control

New catalogs offer design engineers important reference tools

MASTER CATALOG 57-S

More than a catalog, this complete volume supplies comprehensive design engineering data on automatic transfer switches, remote control switches, contactors, relays, solenoids, and electric plant control.

For the engineering specialist who is concerned with components of the ASCO electromagnetic control line, individual catalogs are available covering:

57-S1 AUTOMATIC TRANSFER SWITCHES
. . . designed to transfer a load automatically from a normal source to an emergency source upon failure or reduction in voltage of normal source. For all classes of load, mechanically or magnetically held.

57-S2 REMOTE CONTROL SWITCHES
. . . for convenient and accessible control of power and lighting circuits from any number of control stations. For all classes of load, mechanically held.

57-S3 CONTACTORS
. . . designed to allow unlimited combinations, including multi-pole, special contact arrangements and materials, and other "engineered to fit" features. For all classes of load, normally open and normally closed, magnetically held.

57-S4 RELAYS
. . . magnetically and mechanically held in unlimited pole combinations — plus a highly diversified line of special purpose relays listed as standard catalog items.

57-S5 SOLENOIDS
. . . A-C and D-C, catalog listed or engineered to your requirements.

57-S6 ELECTRIC PLANT CONTROLS
. . . complete systems and components, paralleling, changeover, and alternating panels, load-demand controls, battery chargers and adapter units.

Additional technical literature . . .

Also available is the ASCO engineering study, "Factors to Consider in the Selection of Automatic Transfer Switches."

Catalog 201 on ASCO Solenoid Valves covers more than 1300 types — 2-, 3-, and 4-way with standard, explosion-proof or watertight enclosures—in a wide range of body materials.

Any of these important reference tools may be had simply by writing Automatic Switch Company — *on company letterhead only, please.*

Automatic Switch Co.
50-G Hanover Road, Florham Park, New Jersey
FRontier 7-4600

ASCO

NEW PRODUCTS

processing applications. Construction features include a new type glass center electrode seal and a 95 percent aluminum oxide insulator.—Auburn Spark Plug Co., Auburn, N. Y.

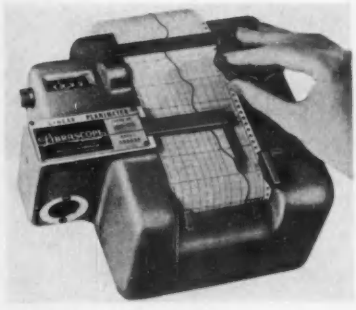
Circle No. 17 on reply card

EASILY INSTALLED

Both fast and slow transient pressures at any two points in a hydraulic or pneumatic system or on an aerodynamic model can be measured with a new differential pressure indicator. The instrument can also be used for short term measurements of the difference or sum of steady pressures, again at any two points. Maker claims the instrument is the only commercial fast-response crystal-type transducer that can be calibrated by conventional static methods. Momentary grounding of the input signal removes all the electric charge generated by the static pressure, and permits the measurements of a 0.1-psi change in differential pressure at a 3,000-psi level. High-pressure adapters can extend this range to 100,000 psi if necessary. Frequency range of the pickups is from 0 to 50,000.—Kistler Instrument Corp., North Tonawanda, N. Y.

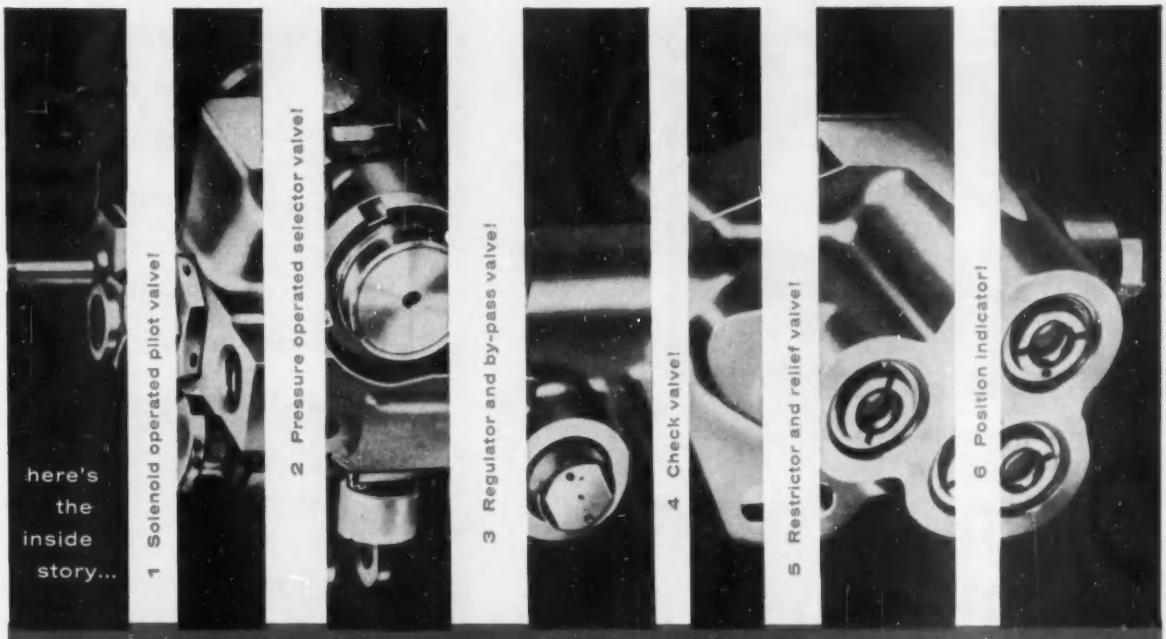
Circle No. 18 on reply card

INFORMATION DISPLAY INSTRUMENTS



SEMIAUTOMATIC

The Model 601 Linear Planimeter, a small desk-size unit, can be used for integrating data from chart recordings of all process characteristics such as flow, pressure, temperature, etc. Designed to accept chart sizes up to 3 1/8



the new dimension in component packaging!

Weston's Pneumatic Actuator Control Valve Package Combines 6 Components in a Single 6.4 lb. Unit!

While controlling the pneumatic actuator, this weight and space saving valve also provides for snubbing pressure at the opposite end of the stroke. It affords extremely fast operation (maximum at .04 seconds) and low leakage (10 cubic inches per hour). The selector valve is non-interflow and detented to maintain position. If you have a weight and space problem, let Weston's team of specialized package engineers solve your specific application.

weston BW a subsidiary of Borg-Warner Corporation

HYDRAULICS LIMITED 10918 BURBANK BLVD., NORTH HOLLYWOOD, CALIF. DEPT. CE-10

Export Sales: Borg-Warner International 36 South Wabash Ave., Chicago 3, Illinois
Eastern Representative: Mr. W. R. Beckerle 14 South Boro Lane, Glen Rock, New Jersey Telephone: GIlbert 4-2094
Midwest Representative: Mr. E. A. Polowniak 11767 Fawnridge Drive, Kirkwood, Missouri Telephone: YOrktown 6-4861

NEW PRODUCTS

in., it features a variable-speed, foot-control drive that permits the operator to traverse at any desired speed. The pointer is positioned by means of a hand-controlled knob. The unit can handle 2 ft of chart in 15 sec, with an optimum accuracy of 0.1 percent. Power requirements are 35 watts at 115 volts ac or dc.—Librascope, Inc., Glendale, Calif.

Circle No. 19 on reply card

RESPONDS TO 0.5 DEG F

An on-off signaling type, this new transistorized temperature controller is adaptable to either thermocouples or resistance bulbs. Maker says the unit can act on a change of only ½ deg F. Regular ac line voltage precludes a standard cell and battery and thus the need for period standardizing. Calibration is guaranteed to within ¼ of 1 percent of scale span.—Thermo Electric Co., Saddle Brook, N. J.

Circle No. 20 on reply card

FOR TURBIDITY & DUST

The Model TIR-6L electronic poten-

for analog computer readout:

modern, compact, mobile

SANBORN

CONSOLE RECORDING SYSTEMS

Up to eight problem variables can be recorded in inkless, permanent, rectangular-coordinate tracings – with Sanborn's improved six- and eight-channel 156-, 158-5490 Console Systems. Less than four feet high and about two feet in width and depth, these Systems are completely mobile and designed for maximum operating convenience. Controls and indicators on the sloping top panel include individual-channel attenuation, position, balance, sensitivity and stylus heat adjustments; switch for turning off B+ of output amplifiers; chart drive motor switch (can also be remotely controlled); code marker and/or one-second interval timer stylus switch. The Recorder unit, either six or eight channels, features paper loading from the top, and nine precisely controlled speeds from 0.25 to 100 mm/sec. Four dual-channel DC Driver Amplifiers of current feedback design are housed below the Recorder, and are mounted on a chassis which may be withdrawn for inspection.

Electrical specifications of the Console Recording Systems include a basic sensitivity of either .01 volt/chart division (5490 types) or 0.1 volt/chart division (5495 types); linearity of 1%; drift less than 1/2 chart division/hour (5490), less than 1/20 chart division/hour (5495); flat frequency response to 20 cps, down 3 db at 60 cps for all amplitudes to 5 cm peak; either single-ended or push-pull input signals of 5 meg. impedance (each input lead to ground).

A useful companion instrument is the new Sanborn Model 183 Programmer, designed to provide a connecting link between an analog computer and the Console Recording System. Shown mounted at the top rear of the Console, the Programmer operates the Console in the following automatic sequence: turns recorder drive on – feeds calibration signals to all channels – reads initial DC levels of computer – closes contacts to start computer problem – records computer output for a preset chart length – turns off recorder drive and resets itself for another cycle.

Further technical data, prices and delivery information – on the 5490/5495 Console Recording Systems and two- to eight-channel 5475/5480 Systems are available on request from your Sanborn Sales-Engineering Representative or the Industrial Division in Waltham.

40th ANNIVERSARY 1917–1957 SANBORN COMPANY

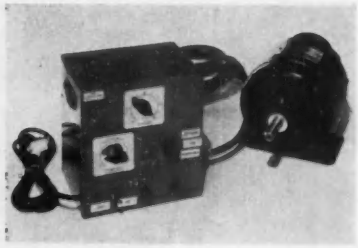
SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman Street, Waltham 54, Massachusetts

NEW PRODUCTS

tiometer recorder, shown above, is one of a line of instruments with selective sensitivity and range. For example, one model used for monitoring contamination of boiler condensate has a full scale range of from 0 to 3 ppm of contaminant. Since both sensitivity and range are adjustable, a wide variety of turbidities and dusts can be monitored closely.—Ess Instrument Co., Bergenfield, N. J.

Circle No. 21 on reply card

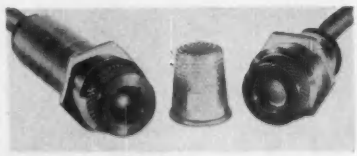
CONTROL DEVICES



SPEED CONTROL

Designed to operate any shunt or compound-wound dc motor, up to ¼ hp, from a 117-vac supply, the Model SC-¼ electronic motor control provides variable speed from zero to full at essentially constant torque. Maker claims the unit will maintain set speed regardless of line variations as high as 20 percent. It also incorporates an adjustable dynamic brake to provide any desired degree of braking. Armature power is supplied from a rugged NL-710 Thyratron rated at 2.5 amp, with 30-amp instantaneous peak rating. Heavy-duty steel case measures 8⅛ in. high by 7¼ in. wide by 5¼ in. deep.—B & B Co., Oakland, Calif.

Circle No. 22 on reply card



NEW LIGHT SOURCE

Designed for close-proximity use with miniature photoelectric cells, this new light-beam projector can be mounted in a single ⅛-in.-diam hole. It operates on a nominal 0.15-amp in-

WIN AN ENGINEER!

Well, with all this advertising for engineers, and with quiz-contests so big . . . it was only natural that some adventuresome advertisement would put the two together as follows:

Win an engineer! Simply describe in 25 words or less why you like Benson-Lehner OSCAR J. Of course, everyone knows that the OSCAR J is a highly flexible and widely used machine for converting oscillographic data into meaningful form, but aside from that, what else do you like about it . . . why does it give you that good, good feeling? Why do you feel compelled to have one in your home, or to take one with you on camping trips?

benson-lehner *corporation*
11930 Olympic Boulevard, Los Angeles 64, California

OFFICES: LOS ANGELES; SUMMIT, N. J.; WASHINGTON, D. C.; DAYTON, OHIO; TULSA, OKLA.; LONDON; PARIS AND OTTAWA

Service Centers in 19 cities throughout the world.
For a personal file of this series write to Benson-Lehner, Dept. 02 for your Adsmanship Handbook Folder.

MAIL TODAY

OSCAR J CONTEST
Benson-Lehner Corp.
11930 Olympic Blvd.
Los Angeles 64, Calif.

Yet another in the adsmanship series provided as a public service by the Benson-Lehner Corporation. Should you, perhaps, need additional information on the OSCAR J in order to compete, or information regarding other data reduction equipment, send us a note.

I LIKE THE OSCAR J BECAUSE _____

_____

_____

_____

NAME _____ COMPANY _____

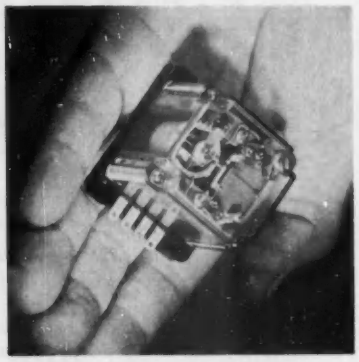
ADDRESS _____

Will you take engineer with slightly stained moustache? YES ___ NO ___

NEW PRODUCTS

put of 6.3 vac or dc. Access to its miniature bayonet base lamp is through an easily removed knurled protective ring.—Autron Engineering, Inc., Los Angeles, Calif.

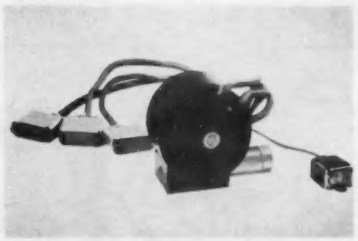
Circle No. 23 on reply card



WILL TAKE 500 G's

This 10-microamp magnetic contact relay, built to Mil-Ord OD-9678, will withstand more than 500 g's. The new sealed unit will also withstand vibrations of 5 to 55 cps at 0.06 in. amplitude. Its insulation resistance exceeds 1,000 megohms. Either ac or dc may be pulled through the contacts. Model 281, shown here, is believed to be the smallest relay of its kind now commercially available with a self-contained reset mechanism. A clear plastic case permits observation of much of the movement.—Assembly Products, Inc., Chesterland, O.

Circle No. 24 on reply card



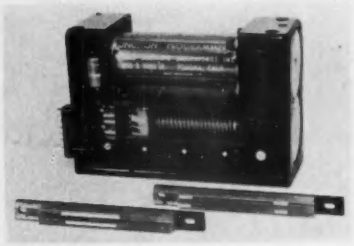
HI-SPEED SAMPLER

The Series 500 high-speed sampling switches are designed for both military and commercial applications. Models are available with up to 60 shorting channels or 30 nonshorting channels per pole, with as many as three poles. Equipped with constant force brushes and lifetime semi-molded contact plates, these switches give long trouble-free service. Normally supplied with

NEW PRODUCTS

a 28-vdc motor with governor and shielded filter, the switch is also available with a 115-volt single-phase 400-cycle hysteresis synchronous motor. Sampling rates are available from 0.5 to 10 rps.—General Devices, Inc., Princeton, N. J.

Circle No. 25 on reply card



TO 16 FUNCTIONS

This new function programmer provides switching as well as potentiometer control of electrical and electronic circuitry in relation to time. Up to 16 separate circuit functions can be accommodated with eight detachable function sweep strips. In addition, a pulsing switch is provided for deriving pulses in ½ sec increments or any multiple of ½ sec. A speed-regulated dc motor with reduction gears drives the contacts along the potentiometer strips at constant speed. Travel time is 50 sec plus or minus $\frac{1}{10}$ sec. Motor normally requires 350 ma and the input voltage may vary from 22 to 36 volts. Under test for missile application, the timer was subjected to vibrations of 20 g's between 20 and 2,000 cps in three planes, accelerations of up to 50 g's in six directions, and 100 g's of shock for 1.3 millisec in three directions—Hubbard Scientific Laboratories, Inc., Pomona, Calif.

Circle No. 26 on reply card

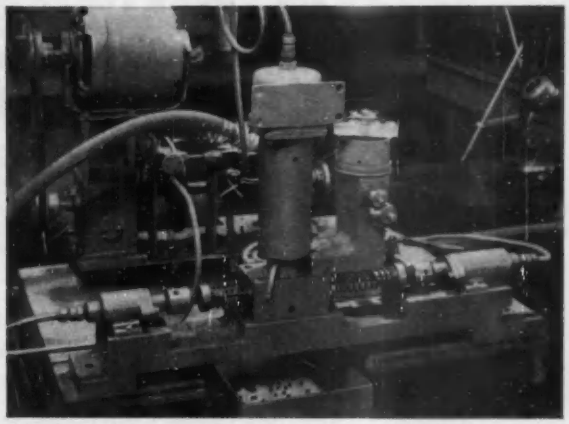
ONE POUND RANGE

A new pneumatic pressure switch, which closes a 1.2-kw circuit under preselected pressure, suction, or differential sum of two pressures, covers a range of from 0.1 in. water to 1 psi. Adaptable to many control and safety functions, the switch may be used to prove the presence or absence of pressure, vacuum, or flow of air and inert or combustible gases. Three interchangeable, color-coded springs adapt the switch to three pressure ranges: 0.1 to 0.5 in. water; 1.0 to 10 in. water; and 4 to 30 in. water.

***Progress** in designing air systems:*

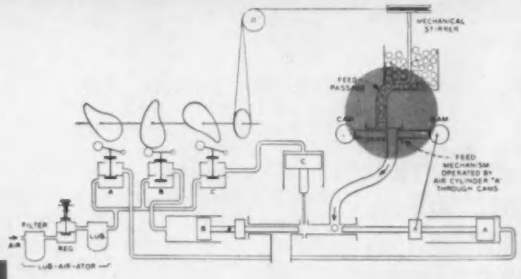
Here's another automating idea: Schrader Air Products in a multi-step punching system

PROBLEM: To pierce tiny balls of lead shot, fast, accurately, and economically.



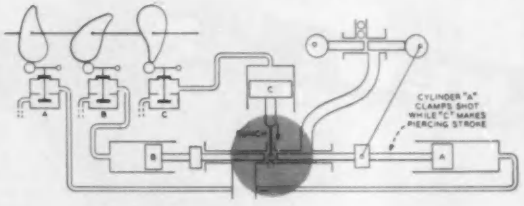
Schrader Products successfully performing at prominent Western plant—feeding, shot-piercing, ejecting—all automatically with air.

SOLUTION: Schrader Air Products designed into a system for automatic operation.



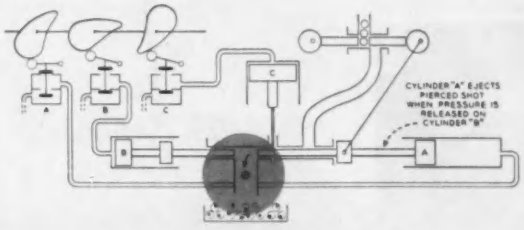
1

FEED: Performance of the cylinders in this system is controlled by cam-actuated Schrader valves. Cylinder A controls split-cam feed; allows the shot to be fed into the machine one at a time.



2

PIERCE: The shot is pushed forward and clamped at the piercing station by cylinder A and cylinder B. Cylinder C pierces the shot.



3

EJECT: Cylinder B returns to its initial position. Cylinder A completes its forward stroke, ejecting the pierced shot. And cycle starts again.

Air's benefits apply in almost any operation you can name: stamping, forming, programming, squeezing or measuring. And the advantages are more important today than ever: speed, accuracy, safety, simplicity, versatility, and—amazing economy. Schrader components are a natural for the designer because they comprise the only complete line of air products to select from. They can be used singly or in combination to perform jobs of amazing variety and complexity. When you design, think of air, and make use of Schrader's engineering facilities to help you specify the right products for your idea. Mail the coupon today.

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QUALITY AIR PRODUCTS

A. SCHRADER'S SON *Division of Scovill Manufacturing Co., Inc.*
471 Vanderbilt Avenue, Brooklyn 38, N. Y.

Please send latest informative booklets which show Schrader's complete line of Air Control Products.

Name_____ Title_____

Company_____

Address_____

NEW PRODUCTS

A simple screwdriver adjustment sets the desired trip pressure anywhere within the range of the installed spring.—Bryant Industrial Products Corp., Cleveland, Ohio.

Circle No. 27 on reply card

ELIMINATES STICTION

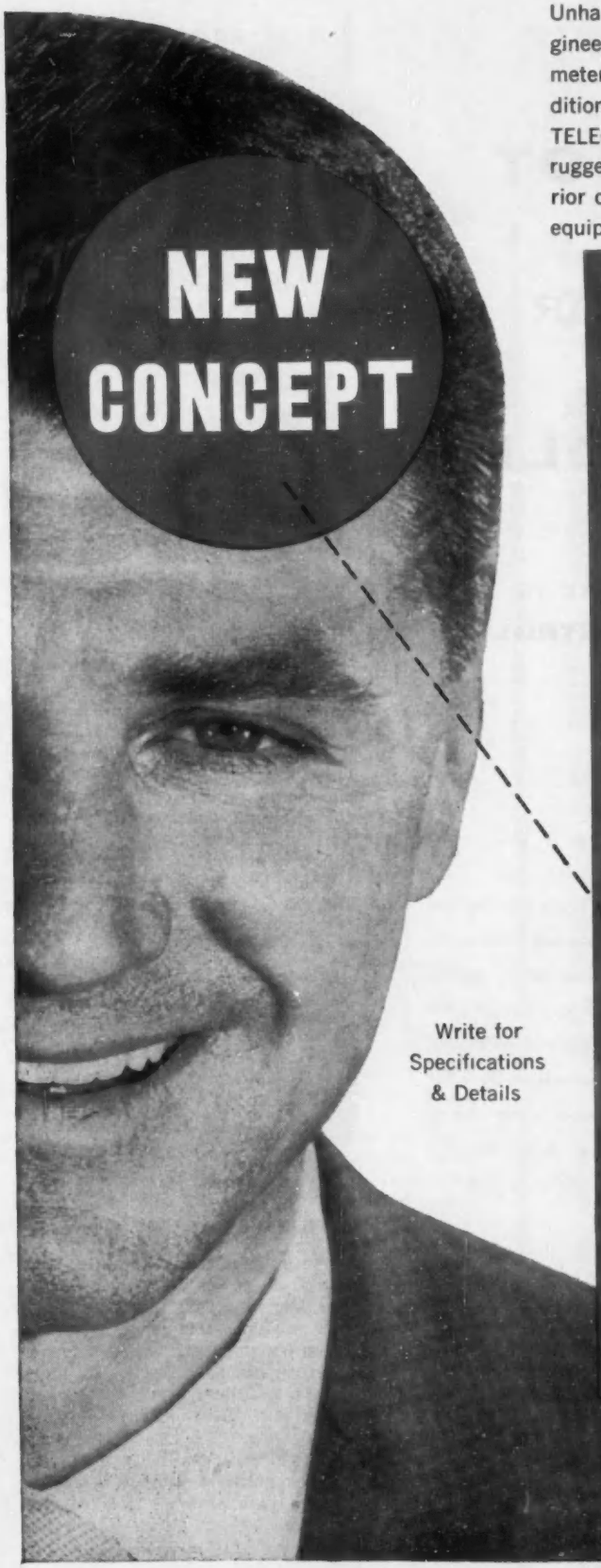
Pictured is a new miniature inertia switch that operates on a radically new, yet very simple principle. Said to be the smallest yet, this switch is designed to eliminate stiction, complicated mechanisms, and wasted space. A single moving part, frictionless in operation, momentarily closes electrical contacts, following impact or acceleration above a preset value. Switch setting is easily adjustable and has a tolerance of plus or minus 0.15 g. Unit occupies ½ cu in. and weighs ¾ oz. —Safe Lighting Co., New York, N. Y.

Circle No. 28 on reply card

POWER SUPPLIES

HIGH-VOLTAGE POWER

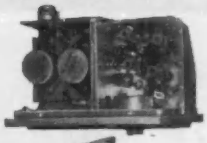
The Model N-413 high voltage power supply is designed for use in the field of scintillation counting or ionization chamber work. Its 10-ma capacity enables it to furnish power simultaneously to several RCA #6810 photomultiplier tubes for coincidence work. Out-



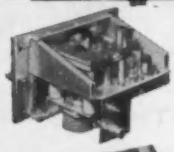
Unhampered by traditional thinking, TELECHROME engineers have developed an entirely new concept in telemetering equipment. Today's new environmental conditions and distances for missiles require new designs. TELECHROME units are unequalled in compactness, ruggedness* and dependability. Because of their superior qualities these highly efficient units are replacing equipment of other manufacture.

Write for
Specifications
& Details

Direct FM Transmitters Crystal controlled 215-235 megacycles. 125kc deviation.

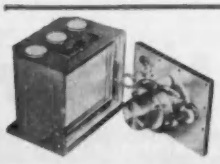


Model 1462—6" x 4¼" x 3⅜"
50 to 80 Watts



Model 1463—5 1/32" x
3 3/16" x 4"
15 to 30 Watts

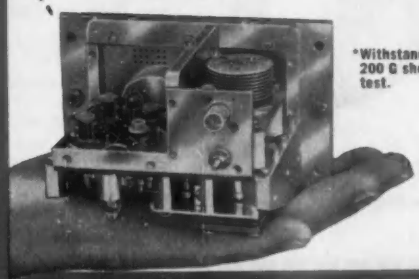
Model 1472—4" x 1.5"
x 2.7"
2 Watts



Model 1460—5" x 4⅝" x 3 1/16"
RF Amplifier
15 to 30 Watts

Model 800—4.5" x 1.3" x 1.4"

SUB-CARRIER OSCILLATOR. Deviation stability ±1% of band width. Deviation linearity less than 1% of band width under all conditions measured from a straight line drawn between end points.



*Withstands 200 G shock test.

TELEMETERING TRANSMITTERS
HIGH POWER
IN SMALL PACKAGES

TELECHROME
INCORPORATED

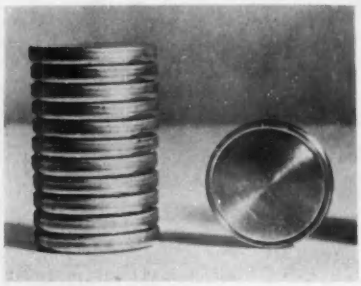
The Nation's Leading Supplier of Color TV Equipment

28 RANICK DRIVE
AMITYVILLE, N. Y.
Lincoln 1-3600

NEW PRODUCTS

put voltage ranges from less than 500 to 5,000 vdc; regulation of 0.005 percent is held for changes in both line and load; and ripple and noise are held to 50-mv peak to peak at full voltage and load. A standard cell provides for reference.—Hamner Electronics Co., Inc., Princeton, N. J.

Circle No. 29 on reply card



EASILY RECHARGED

Slightly larger than a half dollar, the hermetically sealed nickel-cadmium button cells pictured above are available in two sizes, 0.25 and 0.5 ma. These tiny units were developed specifically for miniature and subminiature electronic and electrical applications. Principle features are rechargeability, hermetic sealing, rugged construction, and low internal resistance. —Gulton Industries, Metuchen, N. J.

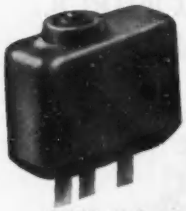
Circle No. 30 on reply card

TRUE RMS REGULATION

Designed specifically for use in the control of power-line voltage variations, the Model 601 automatic voltage regulator is completely independent of power factor. Maker says the unit is particularly useful in areas where line voltage is subject to wide fluctuations. When operating in a 50-to-70-cps frequency range, the instrument will still provide a true rms voltage regulation. Output is continuously adjustable over a range of plus or minus 10 percent of 115 volts. Output will be regulated as long as the

FOUR PROVEN ANSWERS TO SWITCHING PROBLEMS

Subminiature sealed switch is environment-free; mounts interchangeably with MS25085

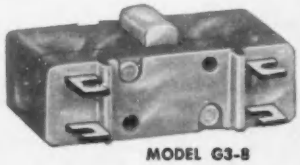


MODEL EF-3

Single Pole, Double Throw
Move. Differential, .004 Max.
Overtravel, .003 Min.
Oper. Force, 5 to 17 oz.
Release Force, 60 gram
Elec. Life Ratings:
150,000 ops. @ 125/250 V. A.C., 2.5 AMP.
100,000 ops. @ 125/250 V. A.C., 5.0 AMP.
50,000 ops. @ 30 V. D.C., (2.5 AMP., IND.; 4.0 AMP., RES.)
Amb. Temp., −65° to +180° F.

Sealed in a corrosion-resistant, treated aluminum enclosure, this tiny switch is environment-free; highly vibration and shock resistant. It carries 5 amps. at 125/250 V.A.C. with an electrical life rating of 100,000 operations. Low operating force and small movement differential make it ideal for bi-metal temperature, diaphragm operated and other "feather-touch" devices, while small size permits mounting singly or ganged in restricted space. Rugged and dependable, it has positive snap action.

Tiny 40 amp. basic switch has high capacity, longer life and constant stability of tolerances



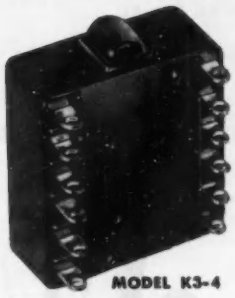
MODEL G3-8

Measuring only 1¾" x 43/64" x 35/64", the Electro-Snap G3-8 Basic Switch handles current ratings up to 40 amps. A new method of combining Electro-Snap's double-break action with a heavy-duty switching element assures electrical and mechanical life of 100,000 cycles at large capacities; also provides constant stability of tolerances and accurate repeatability. New plastic compound case gives the switch an ambient temperature rating of —100° to +300° F. with extreme shock resistance. Small size makes it ideal for motor controls and compact automation set-ups. A wide range of actuators is available.

OPERATING CHARACTERISTICS

Single Pole, Double Throw
40 AMPS @ 125/250 V. A.C.
@ 30 V. D.C. Res.
Oper. Force, 45 oz. Approx.
Overtravel, .015" Min.
Move. Differ., .055 ± .010

Simultaneous triple-pole switch interrupts 3-phase ac. circuits; 6-circuit control in a small package



MODEL K3-4

Triple-Pole, Double Throw
15 AMP., 125/250 V. A.C.
30 V., D.C. Res.
10 AMP., 30 V., D.C., Ind.
Overtravel, .015 Min.
Move. Diff., .028 ± .007
Mech. Life, 1,000,000 ops.
Elec. Life, 500,000 ops.

This Electro-Snap triple-pole switch simultaneously reverses current flow through three windings of a 3-phase motor up to 1 H.P. and interrupts other types of multi-switching installations. Instantaneous "make" and "break" snap-action of the three poles is independent of the speed of actuation—even extremely slow moving cams can be used.

The K3-4 Series offers designers a wide variety of 3-phase circuit hookups for servo-controls, to limit movement of machine members and as a start-and-stop switch which formerly were possible only with complicated relays or a number of separate switches. A large selection of standard actuators is available.

Small basic switch is low cost; directly interchangeable with AN3234 Specs

F2 SERIES

These Electro-Snap F2 Series snap action switches are extra-compact with extremely high electrical capacity for their size. Mechanical and electrical life at 1/32" overtravel is 150,000 operations, minimum, with accurate repeatability and constant stability of tolerances. Self-aligning springs provide contact wiping action rare in a switch of this size.

Durable case of special plastic gives the switch an ambient temperature rating of −100° to +275° F. or +375° F. Available, *at low cost*, in three basic models with a wide selection of actuators.

SERIES F2 BASIC SWITCH: F2-3: Single Pole, Double Throw
F2-2: Single Pole, Normally Open; F2-1: Single Pole, Normally Closed

OPERATING CHARACTERISTICS

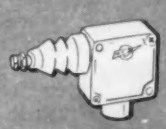
Electrical Rating: 10 AMP. 125/250 V. A.C. 60 cycles
30 V. D.C. inductive and resistive (6 AMP, 30 V. D.C. for Airborne Application)
Operating Force, 7 to 12 oz.
Reset Force, 4 oz. Min.
Pretravel, 3/64 Max.
Movement Differential, .011 ± .005
Overtravel, 1/32 Min.

SEND COUPON FOR MORE DATA

ELECTRO SNAP

PRECISION SWITCHES

BASIC SWITCHES



DIECAST ENCLOSED SWITCHES

HERMETICALLY SEALED LIMIT SWITCHES

CONFORM TO MIL & AN SPECIFICATIONS

ELECTRO-SNAP SWITCH & MFG. COMPANY
4248 W. Lake St., Chicago 24, Ill.

Please send data sheets on switch checked:

- ☐ EF-3 — subminiature sealed
- ☐ G3 — 40 Amp. basic
- ☐ K3 — Triple-pole
- ☐ F2 — Extra-small basic

NAME_____

COMPANY_____

ADDRESS_____

CITY_____ ZONE____ STATE_____

NEW PRODUCTS

input voltage is within 10 percent of the output. A 20-percent control range can also be had by simply changing one connection. At the above range settings the capacity is 3.6 kva and 1.5 kva respectively.–Tel-Instrument Electronics Corp., Carlstadt, N. J.

Circle No. 31 on reply card

FINAL CONTROL ELEMENTS

PRESSURES TO 30,000 PSI

Design of this new control valve provides for a longitudinal stem lift in line with the piston. This is said to cause a considerable improvement in the valve's accuracy. Valve and control units are manufactured for a number of pressures from 6,000 to 30,000 psi, and in sizes from $\frac{1}{8}$ to $\frac{3}{4}$ in. Explosion-proof requirements can be met, and a variety of materials are available.–High Pressure Equipment Co., Inc., Erie, Pa.

Circle No. 32 on reply card

REDESIGNED METER

Widely used for recording, indicating, and controlling process variables involving differential heads, flow, pressures, specific gravity, etc., the Hagan Ring Balance Meter has recently been redesigned to include the following features:

• fully closed measuring system in

You don't have to be over 21

to install and maintain

a Fenwal temperature indicating controller

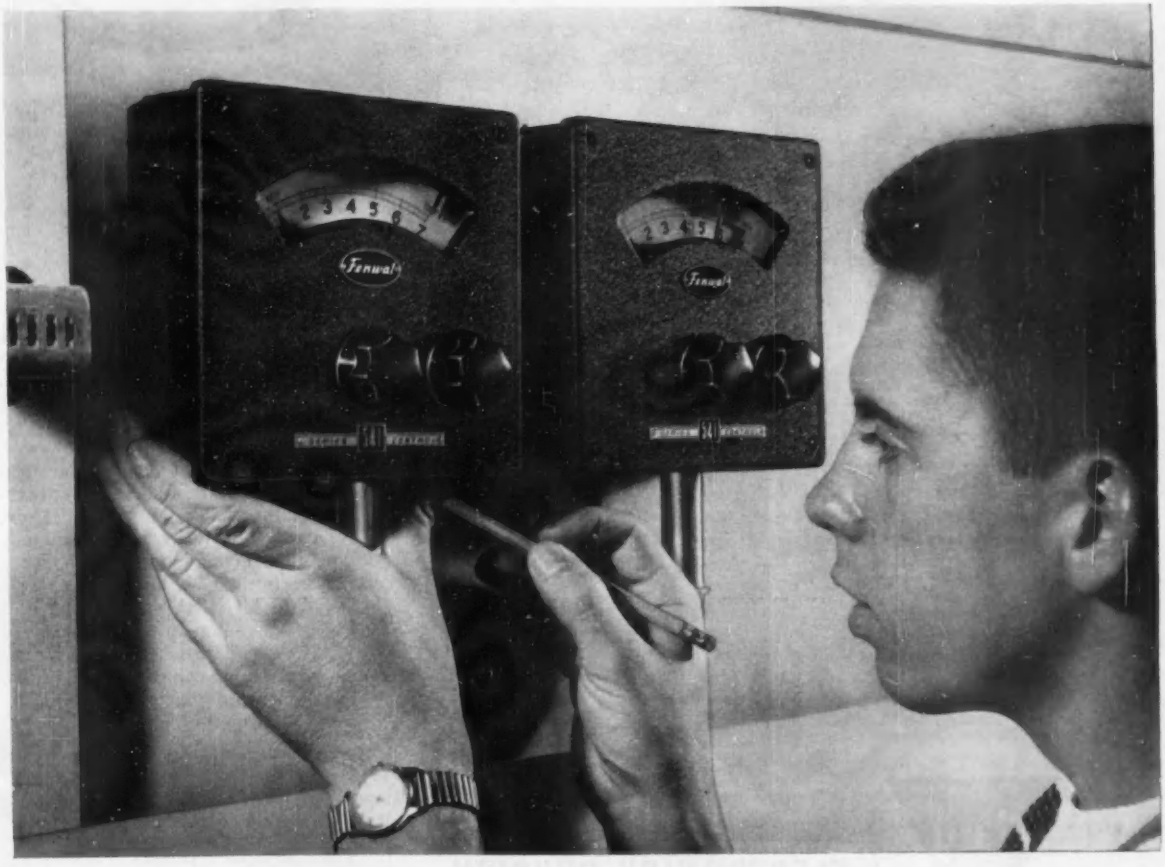
It really is a cinch for an untrained person to install and maintain Fenwal's 541 Temperature Indicator Controller. You don't even have to open the case to adjust it — even its snap switches can be easily replaced without disturbing the internal mechanism. *It's simple!*

In Fenwal's 541 all moving parts are in opposition — wear on one is automatically compensated for and the controller's high accuracy remains unchanged! *It's reliable!*

You can take your choice of temperature range, bulb styles, and one or two circuit controls, current ratings — even the color of the housing. There are literally hundreds of adaptations that can be made from stock! So you get a tailor-made, fit-to-order controller at a competitive price! *It's versatile!*

Drop us a line at Fenwal Incorporated, 5910 Pleasant Street, Ashland, Mass. and we'll send you our catalog MC-139 or our sales engineer, whichever you want.

This is our dual circuit model (we've got hundreds of others) which has two snap switches, each with a set point indicator, that actuates two circuits at pre-set temperatures. Housing in all Fenwal 541's meet NEMA and JIC specifications.



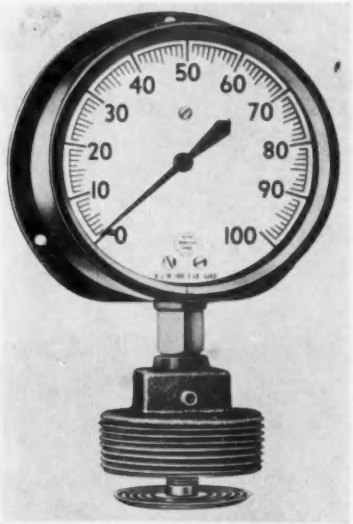
Fenwal CONTROLS TEMPERATURE . . . PRECISELY

NEW PRODUCTS

which no working parts contact the measured fluid;
- stuffing boxes and pressure tight bearings are eliminated;
- dead-weight checking without disconnecting the meter piping, and
- ten times the required ring torque at minimum full scale differential.

—Hagan Chemicals & Controls, Inc., Pittsburgh, Pa.

Circle No. 33 on reply card



NO GASKETS OR JOINTS

Called the Capsule Chemical Gage, this lightweight pressure gage was designed without gaskets or bolted joints. Manufacturer recommends the unit for those applications requiring a short, compact sensing element, and, when properly calibrated at the operating temperature, for use under high-temperature conditions. Its 2½ in. NPT body is easily inserted in any type pipe fitting, preferably above a fast-flowing viscous fluid. When subjected to high temperature, the unit has a maximum pressure rating of 1,000 psi, and at normal temperatures its maximum pressure rating is 2,000 psi.—American Chain & Cable Co., Inc., Bridgeport, Conn.

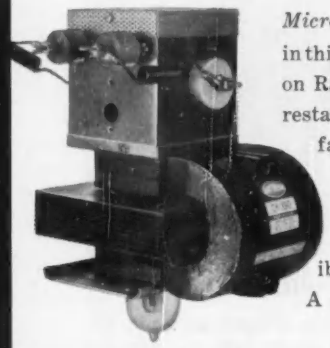
Circle No. 34 on reply card

COMPACT TIMER

The integral Button Controller, Model IBC-2, combines the best features of a cam timer with those of an interval timer in a single, compact, easily adjusted unit. In its basic form, the IBC-2 can serve a wide field

Microwave cooking shaves hours from food preparation time. This is a home-type electronic oven developed by Raytheon for production by appliance manufacturers.

Meals in minutes by electronics– in permanent magnet equipped range



Permanent magnet is C-shaped casting at right of magnetron; box on top is filter assembly.

Microwave energy does the cooking in this domestic electronic oven based on Raytheon's "Radarange" for the restaurant industry. Microwaves are far higher in frequency than broadcast waves—fact, the magnetron tube (at left) steps up the vibrations to an incredible 2,450,000,000 times a second! A vital part of the magnetron is the Crucible Alnico permanent magnet shown in the inset.

This is one of many practical applications for Crucible Alnico permanent magnets. Crucible has been a leading producer of permanent magnets, known for their *consistently higher* energy product, ever since Alnico alloys were developed. You can now order them sand cast, shell molded, or investment cast to every size, shape, or tolerance needed.

It's why an increasing number of manufacturers find the answer to their magnet problem at Crucible. *Crucible Steel Company of America, The Oliver Building, Mellon Square, Pittsburgh 22, Pa.*

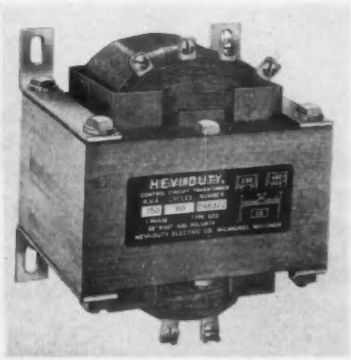
CRUCIBLE first name in special purpose steels

Crucible Steel Company of America

of cycle control applications without the use of relays.—Seely Instrument Co., Inc., Niagara Falls, N. Y.

Circle No. 35 on reply card

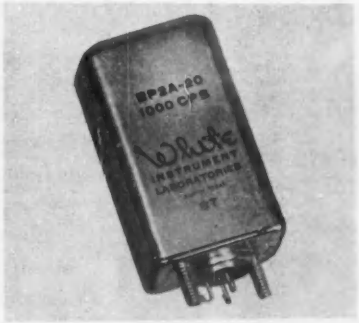
COMPONENT PARTS



RUGGED T'FORMERS

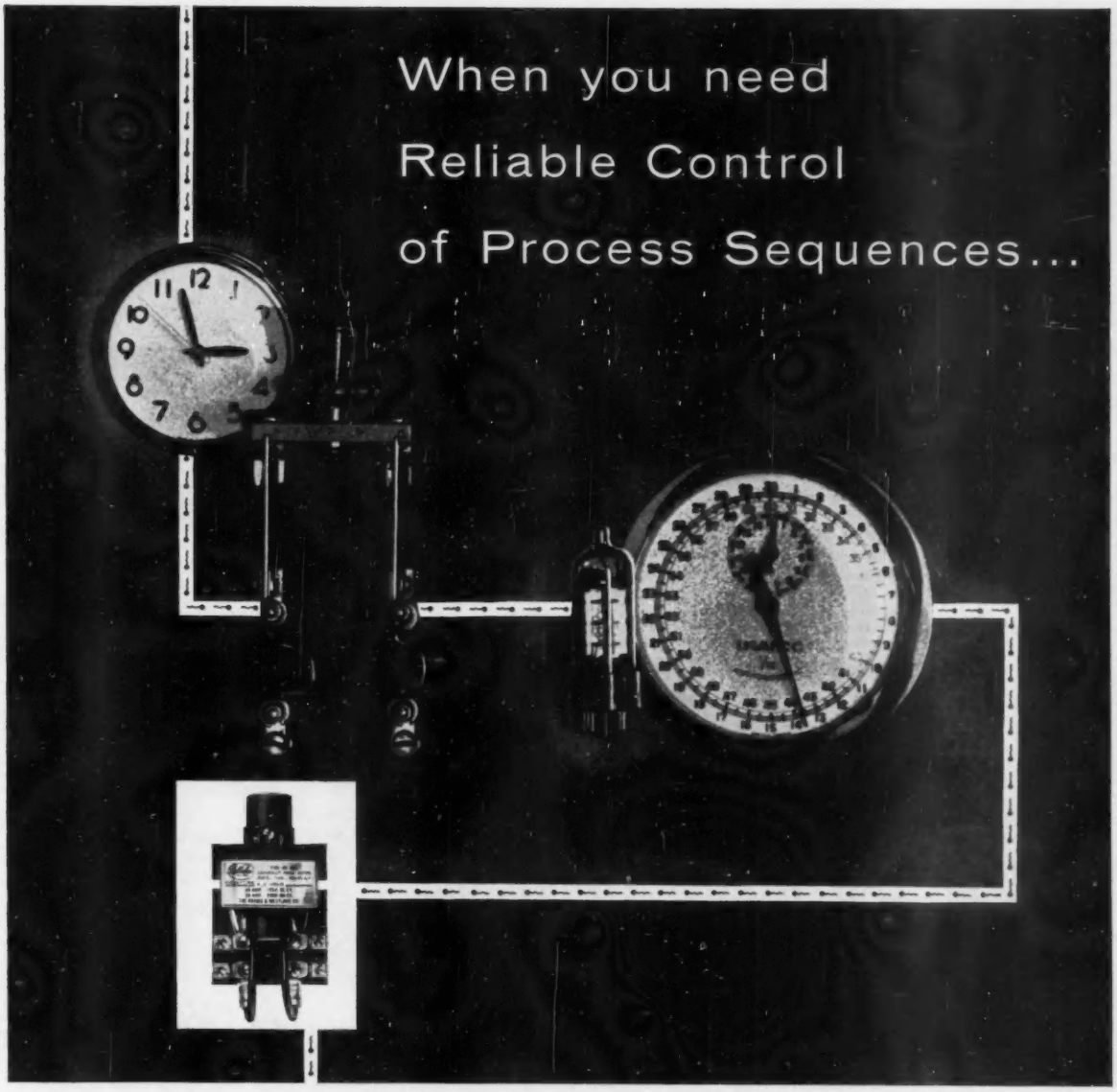
Pictured is one of a new line of heavy-duty control circuit transformers available in standard sizes from 0.050 to 5 kva and able to handle up to 1,000-percent inrush current with only a 5-percent voltage drop. Features include a diagrammatic nameplate, screw-type terminals, slotted mounting feet, and varnish impregnation.—Hevi-Duty Electric Co., Milwaukee, Wis.

Circle No. 36 on reply card



GOOD STABILITY

The BP2 series of bandpass filters, one of which is shown here, has been designed for coupling networks in instrumentation and control amplifiers. Units feature toroidal inductors for linearity and freedom from stray field



you need **Adlake**
mercury-to-mercury
relays

- **Mercury-to-Mercury contact of Adlake Relays gives ideal snap-action with no pitting, sticking or burning.**
- **Hermetically sealed at the factory so dust, dirt, moisture cannot affect them.**
- **Time delay characteristics are fixed and tamper-proof.**
- **Adlake Relays are quiet, chatterless and require no maintenance whatever.**

If you have a control problem, our engineers will be happy to help you solve it. There's no obligation. Write The Adams & Westlake Company, 1181 N. Michigan, Elkhart, Indiana.

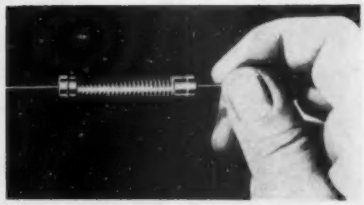
Adlake
100th ANNIVERSARY
1857-1957

The Adams & Westlake Company
NEW YORK ELKHART, INDIANA CHICAGO
original and largest manufacturers of plunger-type relays

NEW PRODUCTS

effects. A wide range of center frequencies and bandwidths are available. Both solder terminal stud-mounts and octal plug-ins can be had in sizes from 1⅞ in. sq and 2 in. high to 1½ sq and 3 in. high.—White Instrument Laboratories, Austin, Tex.

Circle No. 37 on reply card

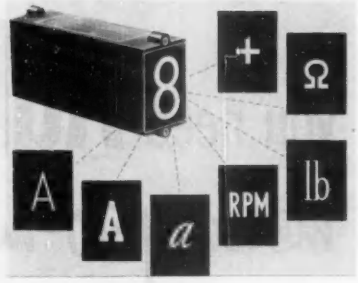


LOW OHMIC VALUES

The Series 850 hermetically sealed metal film resistors are now available in large quantities. Ohmic values as low as 2 ohms in ½-watt size, 3 ohms in 1-watt size, and 4 ohms in 2-watt size are said to be stable and accurate to within plus or minus 1 percent. For any resistance value from 2 ohms to 4 megohms, the units have a positive temperature coefficient within plus or minus 20 ppm per deg C. And because no organic compounds are used, they cannot short out or burn up.—The Daven Co., Livingston, N. J.

Circle No. 38 on reply card

ACCESSORIES & MATERIALS



EASY TO READ

Pictured is an array of new viewing screens for the manufacturer's in-line display. The introduction of colored digits is said to improve the quality of presentation, provide easier reading, and make the display better

in automation...

nothing works if the connector fails!

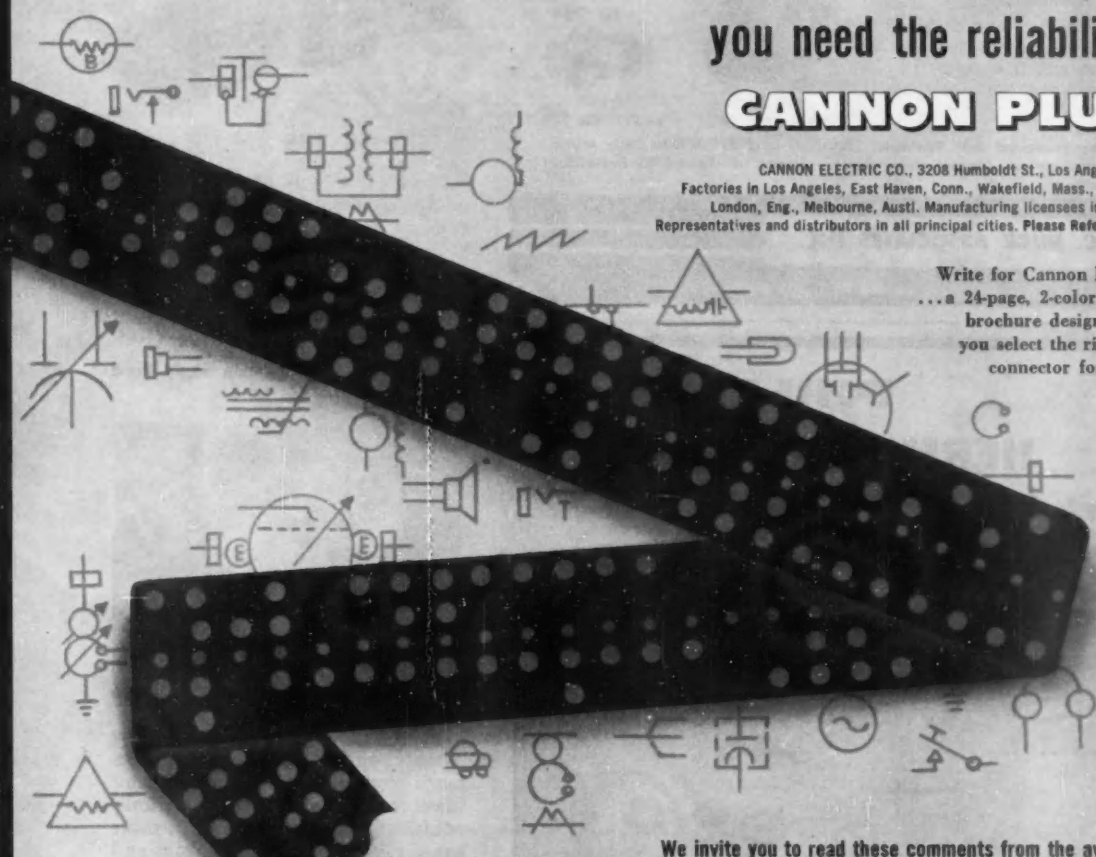
Wherever you go in an automatic control system you find infinite care taken to provide fast, accurate and trouble-free operation in every element... whether it be gears, relays, solenoids, or basic electronic components.

Unless you have duplicate systems, each of these elements *must* function or the system breaks down.

And... in addition... with one or hundreds of electric connectors connecting these elements... *you must have reliability in the connectors you use!*

that's why...

you need the reliability of CANNON PLUGS



CANNON ELECTRIC CO., 3208 Humboldt St., Los Angeles 31, Calif.
Factories in Los Angeles, East Haven, Conn., Wakefield, Mass., Toronto, Can., London, Eng., Melbourne, Austl. Manufacturing licensees in Paris, Tokyo.
Representatives and distributors in all principal cities. Please Refer to Dept. 422

Write for Cannon Plug Guide ...a 24-page, 2-color illustrated brochure designed to help you select the right type of connector for your job.

SINCE 1915 CANNON ELECTRIC

More than 20,000 items made by the world's largest exclusive manufacturer of electric connectors for all electronic applications.

We invite you to read these comments from the aviation field

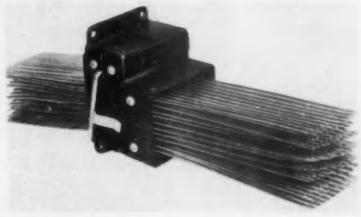
"The ever increasing requirements for high performance aircraft and missiles and their necessary automatic control equipment greatly magnify the importance of component reliability. Many thousands of connectors complete the electrical circuits on which the performance of these aircraft is contingent. High quality and its consequent reliability in the vital area of automatic control equipment is an essential requirement in the progress of aircraft development."

G. B. SHAW, *Vice President—Procurement*
The Glenn L. Martin Company

NEW PRODUCTS

suited to ambient room light. Digits are available in any size or form, and include foreign characters, sans-serif or Roman faces, in light, medium, or bold weights. Size of individual viewing screens is 1½ by 2 in. A single complete display unit sells for $12.50. Voltages from 6 to 48 vac are available.—Industrial Electronic Engineers, North Hollywood, Calif.

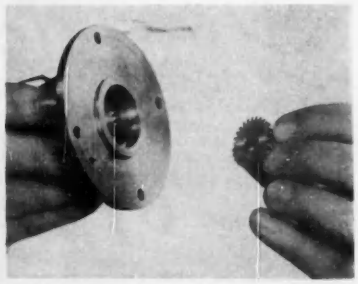
Circle No. 39 on reply card



WEIGHT SAVER

The new flexible printed cable shown above has been designed for application in missiles, aircraft, and computers. Made of silicone rubber with or without glass reinforcement, it features weight savings of 4:1 for signal cable and 2:1 for power cable. —Cinch Mfg. Corp., LaPuente, Calif.

Circle No. 40 on reply card



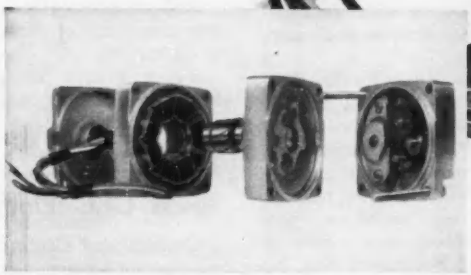
MINIATURE BRAKE

Already applied in computers, antenna controls, and atomic reactor valve controls, this new magnetically released, spring-set miniature brake has a torque rating of 25 oz-in. and a power consumption of 4.9 watts. Approximate physical dimensions are 1⅜ in. in diam by 2 in. long, and weight is a little over 8½ oz. Designed for dc application, these units are wound for 28 volts. A special metallic bonded friction lining gives long wear, high torque, high thermal capacity, and additional strength.—Stearns Electric Corp., Milwaukee, Wis.

Circle No. 41 on reply card

New!

Honeywell Motors



for chart drives, servos, balancing circuits, remote positioners

Now from Honeywell come these newly-designed synchronous and two-phase motors of highest quality. New, sectioned die cast housing . . . new wicking to prevent oil leakage . . . ball bearings to reduce friction . . . printed circuits . . . are some of their many maintenance-saving features. What's more, you can replace any part in two minutes, usually without disconnecting the leads from your installation.

Order these motors in small quantities for prototype development, or by the thousands for production runs. Models charted at right are available for fast, dependable delivery.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, Wayne and Windrim Aves., Philadelphia 44, Pa.

TWO-PHASE INDUCTION

Nominal No-Load RPM*	Gear Ratio	Intermittent Rated Load (oz.-in.)	Max. Starting Torque (oz.-in.)	Power (watts)† Loaded	Current (amps.) Loaded	Temp. Rise Deg. F
330	44:1	4	10	7.6	.11	70
148	10:1	5	20	7.0	.11	70
44	30:1	15	50	7.6	.11	70
22	60:1	30	120	7.6	.11	70

†6.0 watts in field winding, balance in amplifier winding.

SYNCHRONOUS

RPM*	Gear Ratio	Pull-in Torque, Min. (oz.-in.)	Continuous Torque (oz.-in.)	Power (watts) Loaded	Current (amps.) Loaded	Temp. Rise Deg. F
180	10:1	12	12	19	.21	100
180	10:1	3.5	4	13	.11	65
90	20:1	14	12	11	.095	55
60	30:1	13.5	12	13	.11	65
30	60:1	27.5	12	13	.11	65

*1/6 less at 50 cycles. Some speeds available at 25 cycles.

Weight: 29 oz. **Write for Specification 5900-3.**

Honeywell

First in Controls

WHAT'S NEW

(Continued from page 55)
preliminary plans for the reactor which will be built by Zinn's General Nuclear Engineering Corp.

To be located in metropolitan Atlanta, the reactor will take from 18 months to two years for final completion. Total cost: $4.5 million.

IMPORTANT MOVES BY KEY PEOPLE

Probability Expert Heads Univac Engineering

A specialist on the mathematical theory of probability has been appointed vice president and director of Univac Engineering for the Remington Rand Div. of Sperry Rand Corp. In his new position, Dr. Thornton C. Fry will direct research, development and product planning of commercial and military Univac systems and equipment.

After graduating from Findlay College, Ohio, Fry attended the University of Wisconsin where he earned his PhD. degree in mathematics. His subsequent interest centered on the study of probability and its uses in solving engineering problems, particularly those arising in the field of communications. Because of this, he authored the book "Probability and Its Engineering Uses".

The mathematician was formerly assistant to the president of Bell Telephone Labs. Since leaving the labs in 1956, Fry has been serving as a consultant both to the International Telephone & Telegraph Corp. and to Remington-Rand. During World War II, he used his mathematical training as a member of the Fire Control Division of the National Defense Research Committee. And he served as deputy chief of NDRC's Applied Mathematical Panel.

Remington-Rand's new vice president is a fellow of the AIEE, the American Physical Society and the Institute of Mathematical Society. He is also a member of the executive board of Sigma Psi.

Fry will have his headquarters at Remington-Rand's Stamford (Conn.) offices.

New Instrument Division Sparks CEC Promotions

Consolidated Electrodynamics Corp. will aim for a bigger piece of the growing process instrumentation market with a new Analytical & Control Instrument Div. which will coordinate the company's activities in the design, development and manufacture of electronic instruments for the process industries. Heading up the new division as director is CEC veteran


T. C. Fry


H. F. Wiley


C. A. Faust


D. K. Coles


J. P. Day


R. E. Rawlins

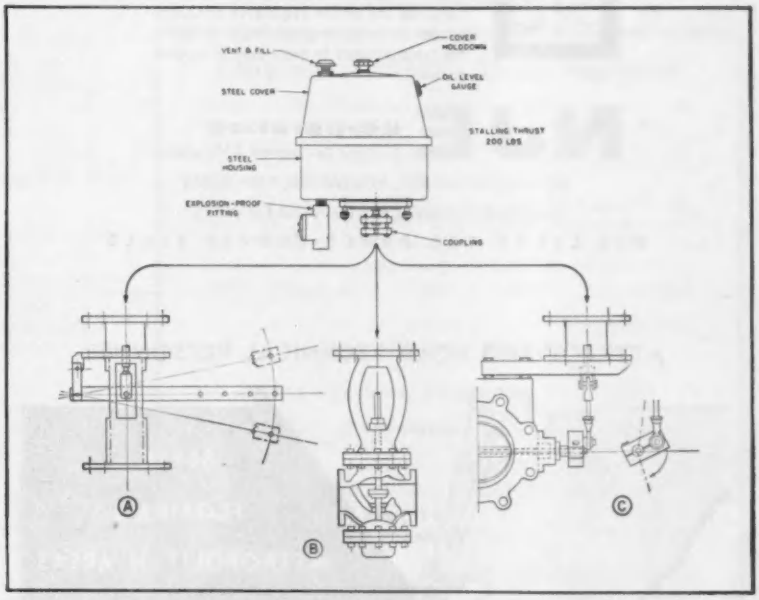
Askania Regulator Company NEWS

Automatic Controls for
PRESSURE, FLOW and COMBUSTION

As demonstrated at the ISA show

A NEW ASKANIA FINAL CONTROL ELEMENT

The Model RF-697 Electrohydraulic Valve Actuator



For Valves Requiring Less Than 200 lbs. Thrust

The Askania Model RF-697 Electrohydraulic Valve Actuator comprises a self-contained unit designed for proportional-position control, using signals from an electronic controller, manual station or directly from a measuring element.

Smaller, more compact and designed for operating valves with ½ to 1½ inch stroke requiring less than 200 lb. thrust, it operates from low level a-c or d-c signals. The d-c range is 1-5 or 4-8 milliamperes. For operation on a-c signals internal rectifiers are provided.

Design Provides Outstanding Operating Advantages

Exclusive design assures *stability*, *fast response*, and *dependable operation* marked by an ABSOLUTE MINIMUM OF MAINTENANCE. Note these important operating advantages:

1. Entirely self-contained
2. Operates directly from controller without relays or converters
3. Mechanically simple
4. Easy to mount on valve—simple to install
5. Competitively priced
6. Designed to meet Underwriters' Laboratories' explosion-proof requirements for Class I, Group D, Division 1 service.

Wide Valve Mounting Adaptability

The Model RF-697 Valve Actuator can be mounted on practically any valve. Typical valve mountings are shown at the right, above:

A. Mounted to provide a lever arm
B. Mounting for sliding-stem valve
C. Mounted on butterfly valve

Important Specifications

Valve Stem Speed...5 inches per minute at 150 lb. load
Valve Stem Stalling Thrust...200 lbs.
Valve Stem Stroke...½" to 1½"
Input Coil Resistance...Standard coil resistance approximately 12,000 ohms at operating temperature.

Send for Application Bulletin No. 38.3 for complete information on this new Electrohydraulic Valve Actuator. Write Askania Regulator Company, 266 E. Ontario Street, Chicago, Illinois.

ASKANIA REGULATOR COMPANY
"CONTROLS FOR INDUSTRY"
HYDRAULIC, ELECTRONIC CONTROLS & SERVOS, GENERAL SYSTEMS, ENGINEERING & COMPUTER SERVICE, VALVE ACTUATORS & CYLINDERS

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GENERAL PRECISION EQUIPMENT CORPORATION

GPE

WHAT'S NEW

Harold F. Wiley who joined the company when it was formed in 1937.

Wiley has been director of the company's Technical Service Dept. for the past four years. He is a graduate of Denison University and earned an MS degree in physics at California Institute of Technology.

Filling Wiley's shoes as head man in CEC's Technical Service Dept. is Clifford A. Faust who moves up from assistant director to director. Faust earned his BSEE degree at Iowa State College.

Other executives named by CEC to the new division include: Armand F. Dufresne, chief engineer; and these managers: Lewis G. Farmer, production; Henry Landsberg, quality control; Arthur L. Schleppy, material; and Donald W. Cook, administration.

Last month CEC had two other appointments to announce. In one, Robert D. Ridgeway was named manager of sales operations; in the other, A. P. Stuhrman replaced William D. Nesbit as manager of central manufacturing.

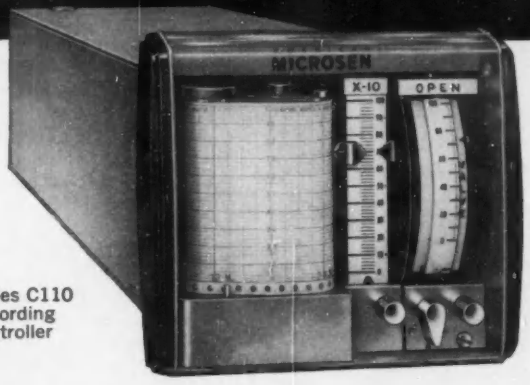
Other Important Moves

▶ **Dr. Donald K. Coles** joins Farnsworth Electronics Co. (Div. of International Telephone & Telegraph) as head of the Farnsworth Solid State Laboratory. For the past 15 years, Coles conducted research at the Westinghouse Research Labs in the fields of infrared and microwave spectroscopy and the application of solid state physics to industrial products. He earned his PhD at the University of Oklahoma after completing his undergraduate work at the Illinois Wesleyan University.

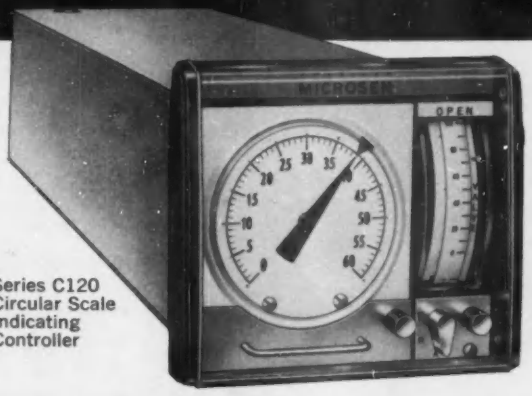
▶ Kin Tel Div. of Cohu Electronics has a new chief development engineer, **John P. Day,** who joins the company from Convair where he was a specialist in the design and development of missile and interceptor aircraft electronic systems. Prior to that, Day was a consultant to Lockheed Missile Systems Div. and headed the instrumentation section of the Research Div. at the Naval Electronics Lab. At Kin Tel, he will supervise development work in electronic instrumentation, and industrial and broadcast television.

▶ New president of Dynac, Inc., a subsidiary of Hewlett-Packard Co., is **Robert E. Rawlins,** general manager, since its incorporation in January 1956. Rawlins replaces former President William R. Hewlett who becomes chairman of the board. Before

NEW TRANSISTORIZED ELECTRONIC CONTROLLERS Interchangeable for complete versatility



Series C110
Recording
Controller



Series C120
Circular Scale
Indicating
Controller

The new 'American-Microsen' Series C100 Electronic Controllers can be interchanged at the panelboard in seconds. A recording controller to an indicating type . . . a proportional-action controller to proportional-plus-reset . . . slow reset to fast reset – any of these replacements is quickly made by pulling one unit out and plugging in the other.

The controller settings of the 'American-Microsen' System are all calibrated and repeatable. When a controller station is replaced, the proportional, reset and rate settings can be made in advance so the process is on control the instant the changeover is completed. No playing around to tune in the control.

When the process is on manual control during a replacement operation, the controller station stays in balance with the actual valve position. Thus the process can be changed back to automatic control without "bumping" or upset. A unique feature of the 'American-Microsen' System eliminates any "balance" or "seal" position between manual and automatic.

These are but a few of the many functional advantages of the new 'American-Microsen' Electronic Control System. Join the many satisfied users of this new approach to process control. Make certain you have the better control and simplified servicing so essential to higher product quality and greater operating economy. Arrange for a meeting with one of our sales engineers to determine the best equipment for your service. *Write for Bulletin RC100.*

Controller Performs These Functions

Measures input signal from transmitter and records or indicates in terms of the measured variable — pressure, temperature, flow, etc. (The Series C110 records on a 3-inch wide strip chart, the Series C120 indicates on a 4-inch diameter scale.)

Provides means of setting the desired value of the measured variable (set point) and compares actual value with desired value.

Transmits control signal, incorporating proportional, reset, and/or rate actions to operate final control element.

Provides means to operate control element manually with simple switch and manual knob.

Ultra-Modern Features Provided

All functions of recording (or indication), controlling (proportional, reset, and/or rate), and manual valve operation *in a single housing.*

Transistorized controller station for ultimate reliability and long service life.

Printed circuitry and miniaturized components for space-saving simplicity.

Plug-in units for complete interchangeability and ease of maintenance.

Ratio, cascade, and other similar control arrangements, using standard instruments.

Direct bumpless transfer from manual to automatic control with no intermediate position.

DC signals of 1.0 to 5.0 milliamperes for instantaneous distance transmission up to 30 miles.

Controllers are compatible with any unit of other manufacture using the standard 1 to 5 milliampere DC signal.

MANNING, MAXWELL & MOORE, INC.

MANNING MAXWELL & MOORE INC. M&M TRADE MARK

INDUSTRIAL CONTROLS DIVISION • STRATFORD, CONNECTICUT

MAKERS OF 'AMERICAN-MICROSEN' ELECTRONIC INSTRUMENTS FOR MEASUREMENT, TRANSMISSION AND CONTROL

WHAT'S NEW

joining Dynac, the new president had spent fifteen years developing electronic instrumentation at Lockheed Aircraft. He predicts that his young company, which has grown to 101 employees in its 18 month history, will have 140 on the rolls before the end of the year.

▶ Hycon Mfg. Co. has appointed **James Leonard** as vice president, customer relations. Mr. Leonard was previously associated with Hughes Aircraft Corp., MESA, a management consultant firm, and the Chrysler Corp.

▶ Clifton Precision Products has elected five new vice presidents. **Louis E. Fagan,** the firm's oldest employee in point of service, was elected senior vice president in charge of manufacturing. **Arnold E. Hayes** was elected vice president and general manager; **Thomas W. Shoop,** vice president, sales; **Alex B. Owan** vice president and plant manager (Clifton Heights); and **W. C. Richardson,** vice president and plant manager (new facility).

▶ Magnetic Amplifiers, Inc., has also elected new officers. They are: **Harold A. Goldsmith,** president, succeeding **S. M. Kellen,** who becomes chairman of the board, and **Herbert Herz,** executive vice-president. Goldsmith and Herz were formerly vice-presidents.

▶ **Seymour B. Cohn,** the new manager of Stanford Research Institute's Antenna Systems Laboratory, formerly headed SRL's microwave group. He is a specialist in microwave research.

▶ **E. Justin Wilson Jr.** succeeds **William J. Barr** as research director of Detroit Controls Corp. at Redwood City, Calif. Before he joined Detroit Controls in 1954, Wilson was with Flight Research, Inc., and Experiment, Inc., both of Richmond, Va., as vice-president. Barr goes to company headquarters at Detroit.

▶ **Stanley S. Walters,** formerly chief of operations analysis for Convair's Astronautics Div., joins the Technical Military Planning Operation in Santa Barbara, Calif., as a member of the Evaluation Section. Walters has also been with: the Army Dept. (consultant), Johns Hopkins University (operations analyst), Cambridge Research Center (R&D specialist), and Rand Corp. (mathematician).

▶ New section chiefs in the Autonetics Div. of North American Aviation, Inc., are **John L. Bower** (automatic industrial controls) and **Lester L. Kilpatrick** (digital computers). Both assignments are in the division's Computer & Industrial Controls Engineering Dept.

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CONTROL ENGINEERING

OCTOBER, 1957

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(100) BIMETALLIC THERMOMETERS. Moeller Instrument Co. Catalog 225C, 12 pp. Discusses construction, actuating element (a temperature-sensitive bimetallic helix), accuracy, etc., of two forms in particular: straight connection for mounting into top of apparatus, and back connection for mounting into the side.

(101) "INCREDUCTOR NOTES". CGS Laboratories, Inc. Periodical, 4 pp. This is a "from time to time" venture by CGS designed to keep readers informed of progress in development and use of high-frequency electrically-controllable inductors. The first issue described inductors and told how they work.

(102) TUBULAR CAPACITORS. Pyramid Engineering Co. Engineering bulletin BTS, 4 pp. Deals with a plastic capacitor for printed circuitry, a completely encapsulated unit with these characteristics: 0.001 to 0.47 mfd capacity ranges; 200-600 voltage ranges; $\frac{3}{8}$ x $1\frac{3}{8}$ in. to $\frac{3}{4}$ x $1\frac{7}{8}$ in. size ranges.

(103) EDGE REGISTER. Electronic Products Div. of Post Machinery Co. Bulletin ER-1, one sheet. Covers a machine designed to control materials handled in a web form by detecting the web edge position and using its displacement to actuate a directional control signal.

(104) ROTARY ACTUATOR. Grand Rapids Div. of Lear, Inc. Product data sheet 101-2, one sheet. Features of the Series 888 actuator include fast response, high holding torque, vibration resistance, and radio noise filter. A metal-powder clutch couples drive and driven members without surface-to-surface contact.

(105) WEIGHING PROCESSES. Weighing & Control Components, Inc. Catalog 12, 20 pp. Compares batch-in, batch-out, and continuous weighing processes, explains how an automatic weighing system can be assembled by building-block techniques, discusses electric and pneumatic weight transmitters.

(106) IMPULSE COUNTER. Electronic Products Div. of Post Machinery Co. Bulletin PD-24, one sheet. Tells about a direct-impulse counter designed for relatively slow counting operations. Speed averages five objects per second, and will hit 10 for brief periods. Counter and photohead can be as far apart as 100 ft.

(107) PRINTED-CIRCUIT LAMINATE. International Resistance Co. Bulletin Lt-2, 4 pp. Gives comprehensive data on size and thickness, properties, current-carrying capacities, foil, and copper finish, makes post-etching suggestions and handling recommendations.

(108) SILICON TRANSISTORS. Transitron Electronic Corp. Bulletin TE 1353, 8 pp. (loose). Covers high-gain, medium-gain, high-frequency, and general-purpose types of npn units designed for low-level signal applications up to 175 deg C. Gives specs and characteristics at 25 deg C.

(109) SECTOR POTENTIOMETERS. Norden-Ketay Corp. Bulletin 415, one sheet. Presents specs and outline drawings for pots designed to operate in damping fluids, and in temperatures of more than 150 deg C. Life exceeds 1 million cycles, resolutions are down to 0.0006 in.

(110) INDUSTRIAL METERING. Neptune Meter Co. Bulletin Ni-57, 12 pp. Combines reports on successful case histories with data on various meters and registers. Also gives maintenance rules, installation suggestions, and results of surveys aimed at saving and controlling costs and improving quality control.

(111 CIRCUIT CONNECTORS. U. S. Components, Inc. Condensed catalog. Illustrates the company's complete line

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CONTROL ENGINEERING
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of connectors, lists key specifications and operating characteristics. Line covers subminiature and miniature power and electronic connectors, pressurized, waterproof, or hermetically sealed.

(112) TAPE HANDLER. Remington-Rand Univac Div. of Sperry Rand Corp. Brochure, 6 pp. Describes a new magnetic unit with built-in controls specifically designed for the Univac File-Computer. Given instructions, it searches a tape automatically for proper data while the computer goes about other jobs.

(113) CONTROL SYSTEMS. Rundel Electric Co. Folder, 4 pp. Illustrates systems for controlling high voltage, processes, gage boards, materials handling devices, load bank testing. Particular attention given to crane control and explosion-proof control systems.

(114) TRANSISTORIZED POWER. Arnold Magnetics Corp. Bulletin S-2-37, 4 pp. All about a low-voltage to high-voltage dc converter regulating against line and load variations simultaneously. Rated at 60 watts continuous duty, it can be used as a plate or bias supply for flight control systems, as a replacement for rotating equipment, etc.

(115) ELECTRONIC COUNTER. Electronic Products Div. of Post Machinery Co. Bulletin PD-28, one sheet. Describes a preset device that counts up to 5,000 units/sec and selects a total count of from one to 100,000 and a warning count of the same amount. Photohead can be as much as 100 ft away from counter without preamplification.

(116) FLOW AND CONTROL. The Hays Corp. Publication 54-766-38, 8 pp. Deals with two Hays products, the Veriflow, which meters, indicates, and totals liquids, and the Veritrol, which controls these operations. Liquids handled include water, molasses, sulfuric acid, coal tar.

(117) PANEL METERS. Weston Electrical Instrument Corp. Bulletin. Covers Weston's group of long-scale (250 deg) panel meters for special applications. Ballistic characteristics, sensitivity, and accuracy are all said to be excellent. Sizes range from 2½ to 5½ in.

(118) TESTING FLIGHT INSTRUMENTS. Norden-Ketay Corp. Bulletin 442, 8 pp. Describes a set for flight-line testing of aircraft pressure instruments and systems. Temperature probes are simulated, and pitot and static pressures generated in checks on altimeters, Mach meters, airspeed indicators, and true airspeed computers.

(119) PRESSURE INDICATOR. Kistler Instrument Co. Bulletin, 4 pp. Details the SLM, a quartz pressure transducer and preamplifier-calibrator, whose accuracy is said to compare favorably with that of the best balanced diaphragm indicator. Static pressures can be calibrated and displayed on an oscilloscope.

(120) OIL CAPACITORS. Industrial Condenser Corp. Catalog 1180. Covers an enlarged line of heavy-duty industrial units available in rectangular, bathtub, and tubular cases. Capacities go up to 24 mfd and 6,000 volts.

(121) TRANSISTOR SERVO AMPLIFIERS. M. Ten Bosch, Inc. Form 1800, 4 pp. Particularly effective in airborne applications, these "Tramps", says the literature, are extremely lightweight and compact, and give up to 9 watts of power for standard servo meters in response to ac signals. Life is 10,000 hours.

(122) RESOLVER. Norden-Ketay Corp. Bulletin 438, one sheet. Gives salient features of a new size 15 resolver, designed Mark 4, Mol 1 by the Bureau of Ordnance. It is said to have a higher accuracy (plus or minus 1 percent) and impedance than any size 15 before it. Range is minus 55 to plus 85 deg.

(123) HIGH-VACUUM STILL. Arthur F. Smith Co. Folder, 16 pp. Gives first-class coverage of the "Rota Film Still", which purifies and isolates a specific compound at molecular weights of 250 or more, the point at which distillation becomes the prey of atmospheric gases.

(124) TRANSISTOR ANALYZER. Norden-Ketay Corp. Bulletin 387C, 4 pp. Describes a transistor curve tracer (Model BCT-300) that measures transistor characteristics by either oscilloscope display methods or direct-reading vacuum-tube voltmeter techniques. Range is 20 watts, 8 amps, or 267 volts.

(125) MAGNETIC DRUM STORAGE. Remington-Rand Univac Div. of Sperry Rand Corp. Brochure, 6 pp. Covers what Rem-Rand calls the heart of the Univac file-computer data-processing system; capacity is 180,000 characters. Data given on construction, operation, speed, functioning, etc.

(126) LINEAL FOOTAGE COUNTER. Electronic Products Div of Post Machinery Co. Bulletin PD-27, one sheet. Tells about an accessory to the Post Decitron electronic counter that makes accurate measurements of continuous production items. One count is equal to one foot; the total in feet and in number of "runs" per day is recorded on tapes.

(127) BERKELEY INSTRUMENTS. Berkeley Div. of Beckman Instruments, Inc. Short form catalog c-704, 8 pp. Presents Berkeley's line of counting, timing, and frequency measuring equipment; special and general-purpose test instruments; and analog computers and precision components for the EASE systems.

(128) STREAM JET PUMPS. Schutte & Koerting Co. Bulletin 4E, 8 pp. Text, tables, and graphs describe a line of air and gas exhauster and compressor pumps that operate on the stream-jet principle. Major uses are in power, process, and manufac-

turing plants, and in research laboratories.

(129) ACCUMULATORS. Industrial Hydraulics Div. of The Parker Appliance Co. Catalog 1530, 36 pp. Deals at length with a piston-type unit for hydraulic systems that absorbs shock of pressure surges, cuts down the size of pumps and motors, dispenses and controls fluids, etc. Data includes capacities, minimum burst pressures, weights, operating temperature ranges, fluids used, etc.

(130) ELECTRONIC COUNTER. Electronic Products Div. of Post Machinery Co. Bulletin PD-10A, one sheet. Describes a reliable industrial unit that can be set to count batches of from one to 1,000 in many combinations, and up to 200,000 per hour with a direct reading totalizer. Two scales are available.

(131) TYPE Q POTENTIOMETER. International Resistance Co. Bulletin A-4a, 4 pp. A lot of detail on the construction, characteristics, and operation combinations of the Type Q control unit.

(132) PRD REPORTS. Polytechnic Research & Development Co., Inc. Vol. 5, No. 2, 6 pp. Features of this issue (January 1957) are a technical paper on a microwave test equipment system for antenna pattern measurements, and an index of "Reports" back as far as 1953.

(133) NEW PUBLICATION. G. M. Giannini & Co., Inc. Giannini Technical Notes, 8 pp. The first issue of this new six-times-a-year periodical carries technical features on an elevator trim system for supersonic aircraft and on calibrating gyros without tapping. There is also a data sheet on Young's modulus of elasticity.

(134) METERING. Milton Roy Co. Application engineering data sheet E-57-1. Shows how controlled-volume pumps are used for metering sweeteners, inhibitors, and metal deactivators to gasoline.

(135) COOLING TOWERS. Milton Roy Co. Application engineering data sheet D-57-1, 4 pp. Another application of controlled-volume pumps (see 134 above), this one involving cooling towers. Tells how the pumps combat corrosion and delignification by metering precise quantities of chemicals to cooling water.

(136) TIMING MOTORS. A. W. Haydon Co. Bulletin AWH MO 805, 2 pp. Contains technical information on the function of three basic dc timing motors, along with a detailed explanation of construction and operation. Cutaway view shows the rotor construction and self-contained gear train.

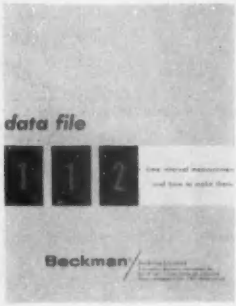
(137) LABORATORY FURNITURE. Metalab Equipment Corp. Catalog No. 4-B, 176 pp. This comprehensive catalog covers a complete line of sectional laboratory furniture for industrial and educational use. It also contains a section on laboratory planning to overcome building limitations. General specifications cover both materials and construction details.

(138) FINE RESISTANCE WIRE. Driver-Harris Co. Bulletin 157, 12 pp. Gives complete data on the electrical and physical properties of several resistance alloys. Complete with charts and tables, the bulletin makes it easy for the user to determine exactly which alloy will prove most economical and effective for a specific purpose.

APPLICATION LITERATURE

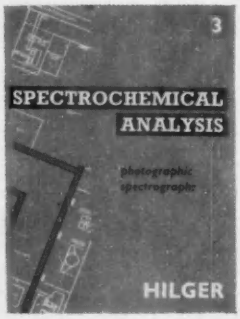
NOTE: Because some of the following literature items are in short supply, we have omitted card numbers and suggest readers write directly to the firms involved.

MEASURING TIME INTERVALS. Dept. 7386, Beckman/Berkeley Div., 2200 Wright Ave., Richmond, 3, Calif. Data File 112, 10 pp. Among the subjects covered in this new 10-page booklet are: an electronic time interval meter; methods for measuring pulse width and elapsed



time; low-frequency period measurements; timing relay operations; testing camera shutter speeds with a time interval meter; and velocity measurements. Discussion of each of the above subjects is accompanied by block diagrams, photos, and schematics. This information should complement the frequency measuring data (Data File 111) described in September.

PHOTOGRAPHIC SPECTROGRAPHS. Information Service of the Jarrell-Ash Co., 26 Farwell St., Newtonville, 60, Mass. Brochure CH403, 24 pp. This publication represents the third in a series of spectrochemical analysis guidebooks prepared by the manufacturer, Hilger & Watts, Ltd., and distributed in the United States by the Jarrell-Ash Co. A variety



of prism spectrographs are described, curves showing how both spectrum lengths and dispersions vary with wavelengths. One Jaco-Ebert plane grating spectrograph is also covered, and is accompanied by a simplified optical diagram of the unit and a table of standard settings. In addition, the brochure describes a variety of standard attachments and a number of useful accessories, including condensing lenses,

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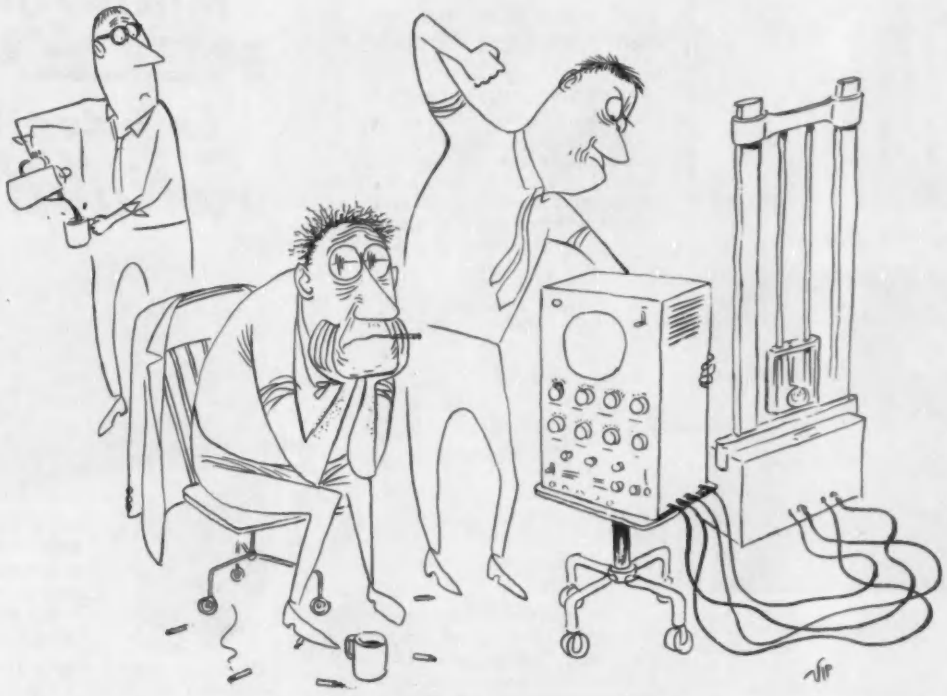

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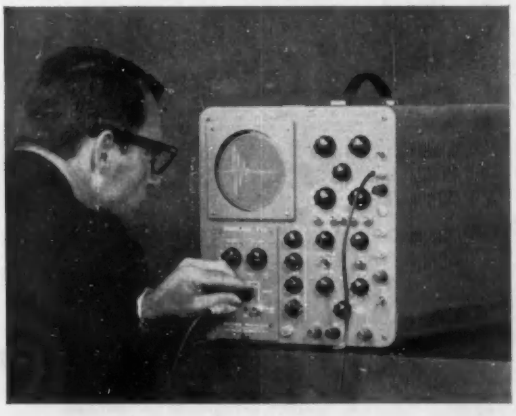

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APPLICATION LITERATURE

fixed and adjustable slits, step filters, stepped sectors, and photographic plates.

ANALYSIS INSTRUMENTATION. Beckman/Scientific Instruments Div., 2500 Fullerton Rd., Fullerton, Calif. Literature Package #4-1 (about 22 pp.). Offered as a package, this new Beckman literature covers some important areas of instrument application in spectrophotometry and gas chromatography. Featured are

separate reports on: fluorescence spectrophotometry; near-infrared spectrophotometry; analysis of aerosol-type propellents by gas chromatography; and the determination of sulfur content by the versatile ultraviolet absorptiometric method. In addition, a two-page application data sheet describes how the Model DK-2 Spectrophotometer is being used to accurately record trace impurities in high-transmittance reagents. Shown is the cover of one of the four-page technical data sheets.

REACTOR CHARACTERISTICS. Control Div. of Magnetics, Inc., Box 391, Butler, Pa. Catalog R-10, 32 pp. After a brief description of the company's standard line of 240-volt and 120-volt saturable reactors, this new booklet presents three full pages of typical application circuits.

A cutaway view on page 6 shows the internal construction of these units. The various electrical definitions and tests used to define the electrical characteristics of saturable reactors are also described in detail. These include: rated load, volt-ampere amplification, time of response, and figure of merit.

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ABSTRACTS

Backlash and its Effect on Complex Systems

From "Combined Hysteresis and Nonlinear Gains in Complex Control Systems" by R. V. Halstenberg of Convair. IRE PGAC paper presented at the Symposium on Nonlinear Control, San Francisco, Aug. 19, 1957.

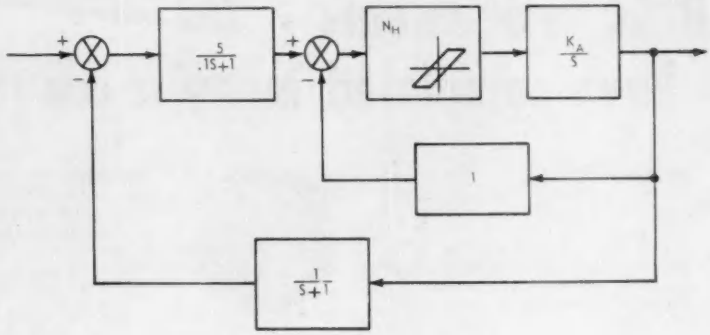
In many closed loop systems unintentional nonlinearities at low operating levels often render attempts at linear analysis useless. One quite prevalent nonlinearity is the one known as hysteresis or backlash. This particular characteristic results from play in gears, bearings, and mechanical connections. Another important but less obvious cause of backlash is friction. Whenever force is the input to a system containing friction, a hysteresis loop is formed whose width is equal to twice the friction. Friction also exists in zero-force linkages found in some aircraft systems. A plot of input versus output for a push rod with finite spring constant would show a hysteresis loop twice as wide as the friction divided by the spring constant.

As important as the causes of hysteresis are the effects produced by hysteresis. The worst result, of course, is a sustained oscillation known as a limit circle. Other effects on a closed loop system include phase lag and gain reduction, and a reduction in steady-state accuracy.

Analysis by means of either describing functions or analog computers is quite helpful. Describing functions can be used to determine the low amplitude stability characteristics of most systems with a single hysteresis loop. An analog computer, however, is much faster and readily provides information on the transient response, not available by describing functions. When more than one hysteresis loop exists in a system, computation is the only general method that is available.

Just as linear systems can be stabilized or improved by appropriate compensation, so can low amplitude nonlinear response be improved by proper shaping of the linear locus. Naturally, the nonlinear problem is somewhat more complex: there is a locus to be avoided instead of a single point. Examples of this type of compensation are given in Appendix II.

If hysteresis and a nonlinear gain element appear together in a system, one approach in a describing function analysis would be to determine a describing function for the combination. Another, much less limited, would be to prepare an amplitude-phase plot for the linear part of the system and apply the describing function in the usual manner. These combined plots will then yield: frequency, gain required to cause a limit cycle at that frequency, and amplitude of the limit cycle that could occur.



The figure above is a block diagram taken from Appendix III in which is given an example of hysteresis and nonlinear gain in series. K_A/s here represents an hydraulic valve and actuator combination. The example determines the effects of a nonlinear K_A on low-amplitude stability.

Adaptive Vs. Linear

From "Adaptive Servomechanisms" by R. F. Drenick and R. A. Shahbender of Radio Corp. of America. AIEE Transactions Paper No. 57-388. Presented at the Summer General Meeting, Montreal, Quebec, Can., June 24-28, 1957.

In this generalized approach to the logical design of "adaptive" servomechanisms, the term "adaptive" refers to control systems which, roughly speaking, monitor their own per-

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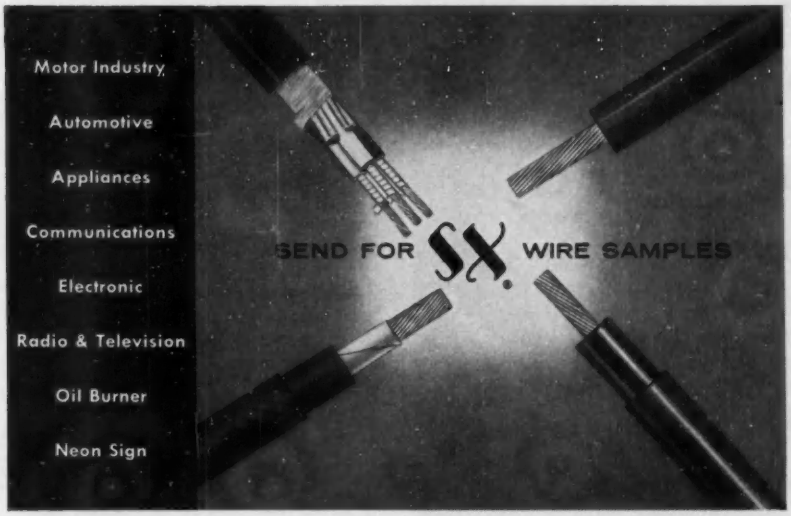

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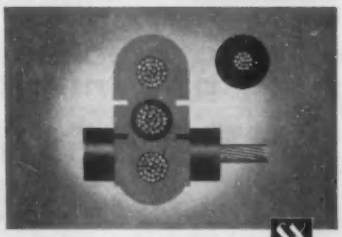

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ABSTRACTS

formance and adjust some of their parameters for better performance.

Underlying the technique described here is the requirement that the servo loop adjust its parameters so as to minimize the steady-state rms error resulting from a polynomial input signal in the presence of noise. This condition specifies a functional relation between the servo parameters and the polynomial input. The physical realization of these functional relationships is treated in the paper and leads to the adaption loops necessary to produce the adaptive behavior.

As an example of the synthesis procedure, the design of a second-order adaptive system is presented. Analog computer results demonstrating that the adaptive system is superior in performance to linear systems of the same order are also included.

New Disc Memory

From "An Air-Floating Disc Magnetic Memory Unit" by W. A. Farrand, North American Aviation. Paper presented at the Western Electronic Show & Convention, San Francisco, Aug. 21, 1957.

This paper describes a new magnetic disc memory unit for handling digital data. The unit, a time-sequenced, recirculating, precessing, and storing memory, uses a magnetic-oxide coated disc that revolves below a headplate containing fixed recording and reproducing heads. The magnetic gap is maintained by an auto-lubricated air bearing that is engaged and disengaged by a solenoid.

Units using 32-loops with densities of 180 cells per inch on the outside track are in operation today with magnetic cross-talk under 2 percent. Readout modulation and base distortion are both less than 5 percent; "write" currents range from 4 to 20 ma. One of the units, containing 85,000 cells on 40 tracks, measures 8¾ in. in diam by 6 in. high.

Controlled Boring Mill

From "Electronically Controlled Machine Tools In Service" by C. A. Sparks, H. W. Kearns & Co., Ltd. An address delivered to the conference accompanying the Instruments, Electronics, & Automation Exhibition, London, England, May 7-17, 1957.

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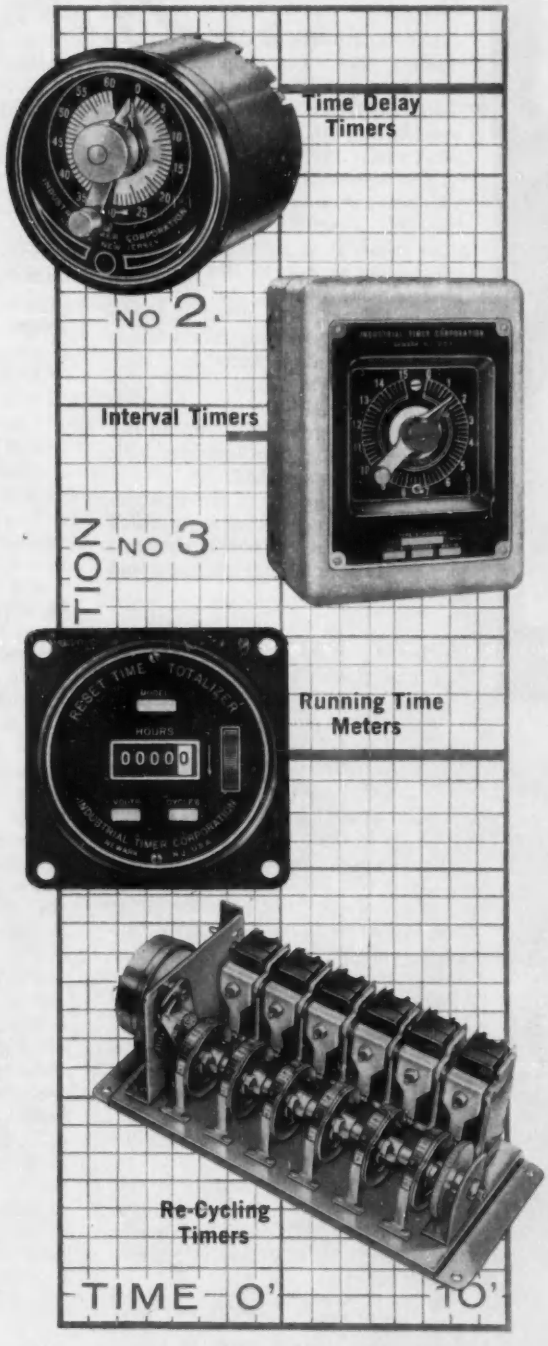

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automatic control of mass-production machine tools. Few details, however, have been published on the new machines designed primarily for the manufacture of single parts or very short runs.

The author hopes his book is a step forward in remedying this situation. He presents some of the problems involved in applying electronic control equipment to this particular class of machine tool, and suggests a few of the solutions, using as an example a new British horizontal boring machine featuring electronic coordinate setting. The machine was originally designed with the idea of making it a workshop proposition, and for this reason only the sturdiest electronic equipment was specified.

A complete history of the new machine's service experience is presented to dispel the theory that it requires a specialized staff for maintenance and operation.

Applied Static Controls

From "Some Applications of Magnetic Amplifiers in Aircraft Generator Protective Systems" by D. L. Plette and J. W. Butler, both of General Electric Co. AIEE Paper No. DP 57-481. Presented at the East Central and Middle Eastern District Meeting and Air Transportation Conference, Dayton, Ohio, May 7-9, 1957.

Much of the progress made in the last five or six years in improving aircraft generator regulation and excitation systems can be attributed to a combination of static magnetic components and dry disc rectifiers. At the same time, most of the protective devices used in these systems have relied on fairly critical relays. Sensitive to acceleration, shock, and vibration, these relays have rather unpredictable operating points. The authors feel, therefore, that both reliability and accuracy of protective systems can be greatly improved by the use of magnetic amplifiers in place of the relays.

Some of the amplifiers' advantages cited: the ability to operate voltage comparison circuits and frequency comparison circuits at a fairly low power level, and to amplify the error signal produced to a level sufficient to operate a more reliable standard relay. Thus voltage to the relay coil is either full "on" or full "off". The use of standard, noncritical relays also permits the system to meet shock, vibration, and acceleration requirements. A final advantage of magnetic amplifiers is their inherent ability to provide time delays, both fixed and inverse.

Circuits described in this paper include under- and over-voltage relays, fixed-time-delay relays, and underfrequency relays. All use magnetic amplifiers and make no additional weight or space demands.

New Open-Loop Device

From "A New Type Step Motor" by Samuel Noodleman, The B. A. Wesche Electric Co. AIEE Paper No. DP 57-464. Presented at the East Central and Middle Eastern District Meeting and Air Transportation Conference, Dayton, Ohio, May 7-9, 1957.

This paper describes a new power device of the open-loop type, a step motor that operates from single phase ac. Operation of this type step motor is on the principle of a squirrel-cage rotor with groups of bars which, when placed in a single phase field, will generate currents that tend to position the rotor in the center of the stator flux. In general, the rotor will move and hold in a position of minimum rotor current. As the rotor moves away from the center of the stator flux, more and more circulating currents are produced. When the center of the rotor bars is 90 deg from the flux center, torque direction changes abruptly. Any displacement of the rotor from its neutral position will develop a restoring torque in the rotor.

When several equally spaced stator windings are progressively energized, the center of the pole flux shifts and the rotor will step and align itself to follow the shifting center. The angular displacement on each step is inversely proportional to the number of poles and phases (at least three phases must be used, however). A two-phase winding would try to position the rotor 90 deg away from the neutral, a point at which the positioning torque is quite unstable.

The unit has a number of unusual advantages. Since it is basically a squirrel-cage rotor with a polyphase stator, motor operation is possible. Also, by using special commutator arrangements or other rotary switching devices, the unit becomes a variable-speed ac induction motor, in exact synchronism with the speeds determined by the commutator.

NEW BOOKS

Using the Algorithm

LINEAR PROGRAMMING: *An Explanation of the Simple Algorithm, by Dakota U. Greenwald, 75 pp. The Ronald Press Co., New York, 1957, $3.00.*

This is a small volume which illustrates step by step how to apply Dantzig's "simplex" technique to find the optimum "solution" for several linear equations in several variables. Unlike Dantzig's original paper on linear programming (Monograph No. 13, Cowles Commission for Research in Economics, 1951), which used the concepts and notations of modern algebra to present a rigorous proof of the correctness of the technique, this little book uses simple college algebra and takes the steps slowly and in detail. The simplex algorithm is primarily a device for hand-computation of problems with less than, say, four variables, though it has been programmed into electronic computers to optimize 100 equations with 1,500 unknowns in less than 8 hours. The present status of linear programming is reviewed by Dantzig, its inventor, in "Recent Advances in Linear Programming", in the January 1956 issue of *Management Science*.

Physical Electronics Today

FUNDAMENTALS OF ELECTRON DEVICES. *Karl R. Spangenberg, Professor of Electrical Engineering, Stanford University. 505 pp. Published by McGraw-Hill Book Co., Inc., New York, 1957. $10.*

Primarily intended as an introductory text on electronics, this book should be of interest to a much wider group than undergraduate EE's. Control engineers, for example, whose experience has largely been with pneumatic or hydraulic devices and who would like to become familiar with the principles of electronics, should find this text quite digestible. Graduate EE's whose formal education covered very little on electronics and nothing at all on transistors could also profit by it.

Not only does the author discuss the operating characteristics of vacuum tubes and transistors, but he also stresses the internal physics of each. He emphasizes the similarities rather than the differences between them. This is accomplished to a great extent through the common denominators of semiconductor and potential theory.

Thirteen short appendixes are included to show the derivation of some of the fundamental relationships. A few examples would be the derivations of the diffusion equation, the thermionic emission equation, and the Child-Langmuir Law. Problems pertaining to each chapter are grouped together in a single section at the back of the book. A bibliography of over 200 references, keyed throughout the text, is also included.

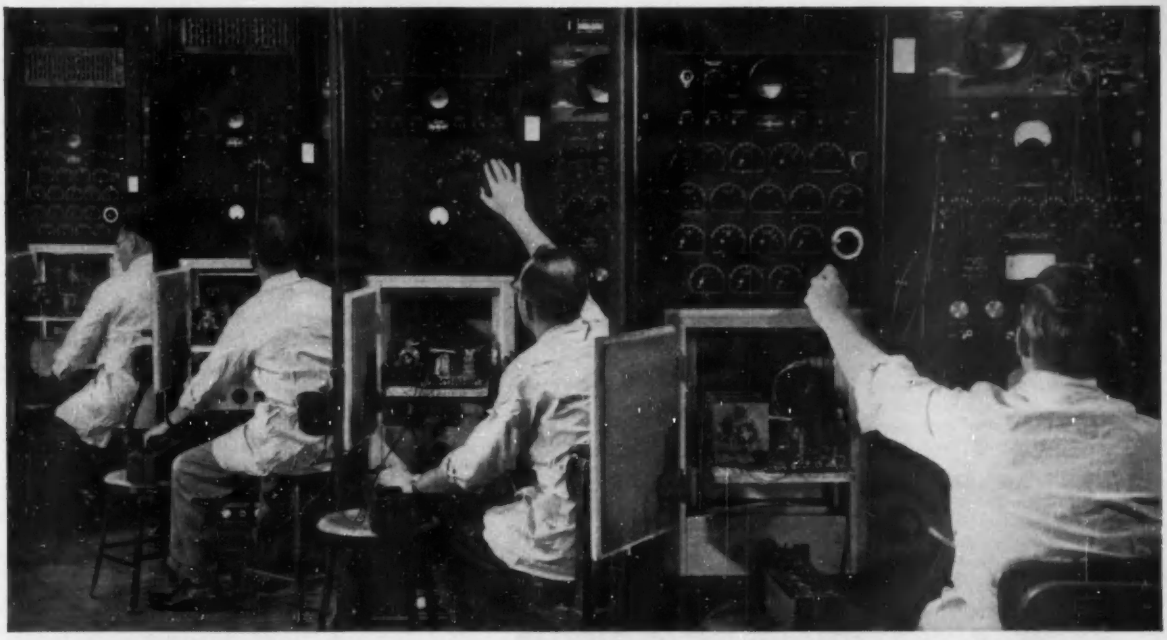
A Needed Text

SYSTEM ENGINEERING: *An Introduction to the Design of Large-scale Systems by Harry H. Goode and Robert E. Machol, 551 pp. Published by McGraw-Hill Book Co., Inc., New York, 1957, $10.00.*

Here is a book that has been badly needed for a long time. The growing body of knowledge about the physical universe has naturally forced the scientist and engineer to specialize more and more. Each specialty has become a field of study in itself, and even the specialty fields are subdividing. Within the special field of servomechanisms, for example, many engineers are specializing in electromechanical servos, or nonlinear electromechanical servos, or even error measuring devices in nonlinear electromechanical servos. In the face of this individual specialization, competition among men and nations in a world of exponentially increasing population is forcing the development of very complex large-scale systems which must unite the efforts of a large number of these specialties toward a common end. This is especially true in the areas of communications, transportation, and defense.

Thus, at the same time that the increasing depth of the smallest area of science is forcing more and more specialization, social and economic conditions are demanding generalists in increasing numbers. Such generalists have been called engineer-scientists, or system engineers. They are the coordinators of the specialties, leaders of teams of specialists, and their jobs get more difficult as the systems get larger and more complex.

This book is a text for the system engineer. It concentrates on the very large systems, such as those for traffic control and telephone networks, so that as many as possible of the methods, parts, and tools of system engineering may be dealt with adequately. The designer of smaller systems will



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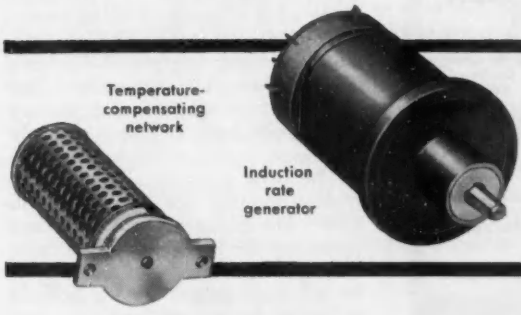

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Rated excitation	115 volts, 400 cycles
Output voltage gradient	.2 volts per 1000 rpm
Output voltage	.6 volts ± 0.05% at 3000 rpm
Phase shift	0 ± 0.1 degrees

AVERAGE MECHANICAL CHARACTERISTICS

Rotor moment of inertia	0.57 oz.-in.²
Operating temperature range	-15°C. to 75°C.
Weight:	
Rate generator	1¾ pounds
Compensating network	¼ pound

Eclipse-Pioneer Division

TETERBORO, N. J.

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AVIATION CORPORATION

thus be more than satisfied by the content of this book.

The writing has a flowing, easy-to-read style that does not waste too many words. The size of the book is an honest reflection of the breadth of the subject. Organization and relative emphasis on topics are harder to assay because of individual preferences on areas of major emphasis. The authors, of course, had to concentrate on those areas which seemed to them most important generally and on those that required more than average space for clarification.

Goode and Machol's organization of the subject goes as follows: After an introduction, a part on "Probability—The Basic Tool of Exterior System Design", which runs some 70 pages. Next a part on "Exterior System Design", which discusses the basic formulation of the problem and tells how to construct mathematical models of the system and experiments to prove their validity. The next 90 pages are devoted to "Computers—The Basic Tool of Interior System Design", and includes discussion of construction features, operation, programming, etc., of both digital and analog machines, as well as analog-to-digital and vice versa converters. The last 200 pages of text are spent on the tools, steps, and equipment of "Interior System Design". This last part includes chapters on queueing theory, game theory, linear programming and group dynamics, simulation, component parts, information theory, servomechanism theory, and human engineering. The book concludes with an epilogue on the economics of large systems, test and evaluation of large systems, and the management of engineering effort.

This book has been designed as a text, and eight of the 31 chapters include a list of problems to be worked out by the student. The problems are answered at the end of the book. Also, 145 references to pertinent literature are made, often with the authors' comments on their particular usefulness to the system engineer.

The book contains all the mathematics necessary for the system engineer, but it is so organized that these parts may be easily skipped over by management people who want just an overall appreciation of the difficult problems these system engineers face. Actually, except in a few instances where the Laplace and Fourier transforms are used, the mathematics does not go higher than fundamental calculus.

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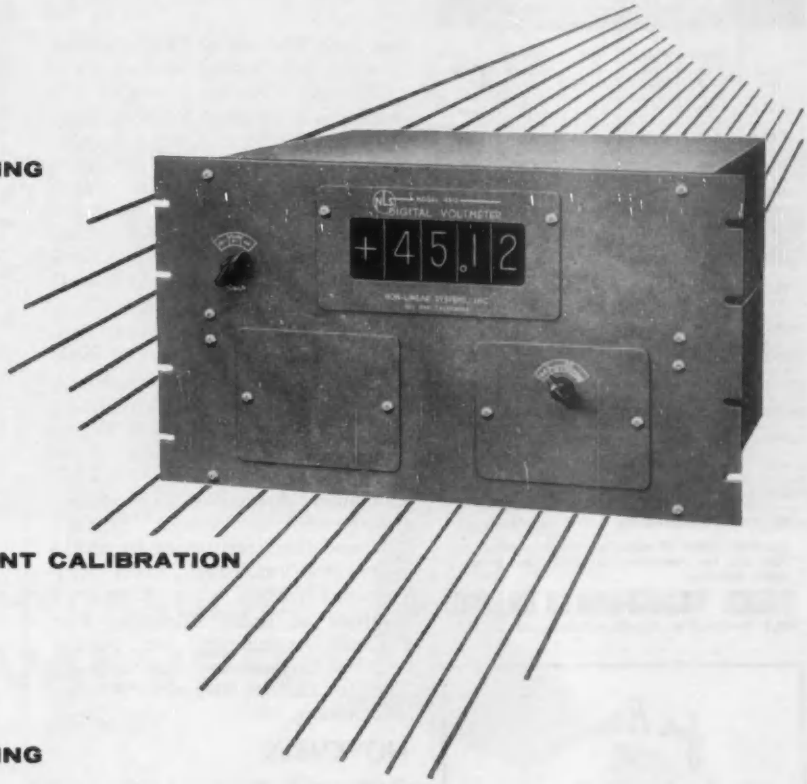

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WHAT'S AHEAD: MEETINGS

OCTOBER

National Electronics Conference, 13th Annual, Hotel Sherman, Chicago Oct. 7-9

American Institute of Electrical Engineers, Fall General Meeting, Hotel Morrison, Chicago Oct. 7-11

American Institute of Electrical Engineers, Feedback Control Systems Committee, "Computers in Control Symposium", co-sponsored by IRE, Professional Group on Automatic Control, and ASME-IRD, Chalfonte-Haddon Hall Hotel, Atlantic City, N. J. Oct. 16-18

Institute of Radio Engineers, Canadian Convention, Exhibition Park, Toronto, Can. Oct. 16-18

National Conference on Industrial Hydraulics, sponsored by Armour Research Foundation and Illinois Institute of Technology, Hotel Sherman, Chicago Oct. 17-18

Computer Application Symposium, sponsored by Armour Research Foundation, (registration fee of $35 includes luncheons), Hotel Sherman, Chicago Oct. 24-25

Institute of Radio Engineers, East Coast Aeronautical and Navigational Conference, Lord Baltimore Hotel and 7th Regiment Armory, Baltimore, Md. Oct. 28-30

NOVEMBER

International Metal Exhibition and Congress (39th annual), International Amphitheatre and Palmer House, Chicago Nov. 2-8

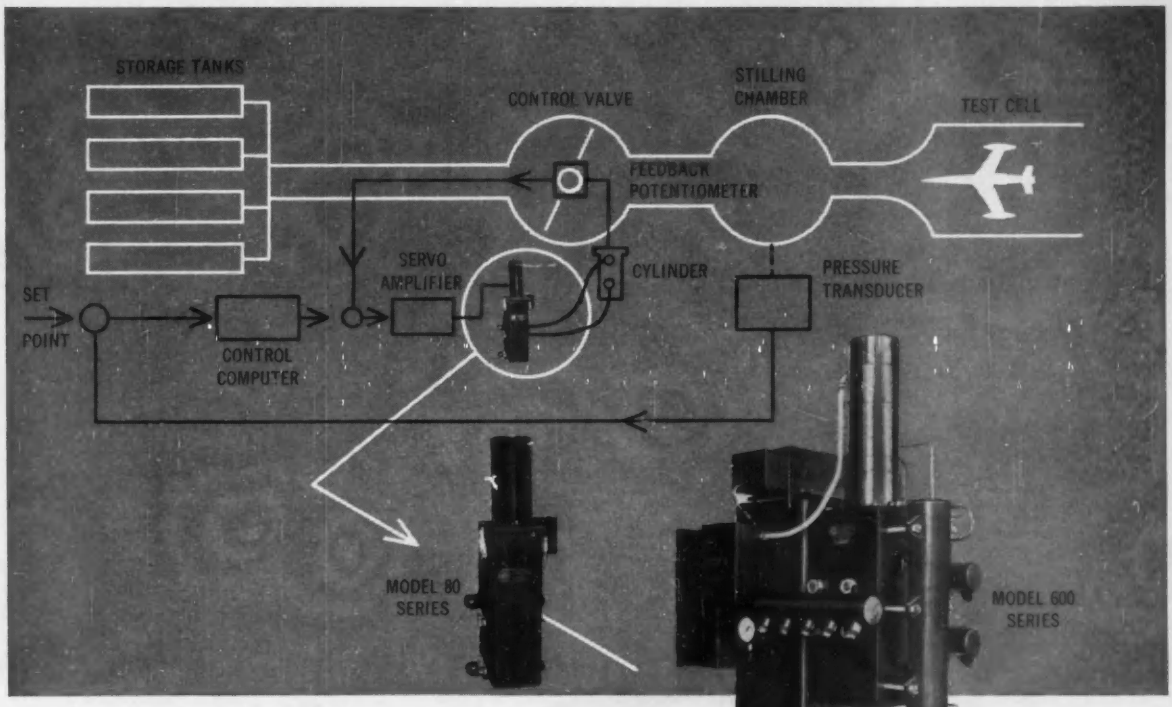
International Congress & Exhibition of Instrumentation & Automation (INTERKAMA), Dusseldorf, Germany Nov. 2-10

American Institute of Electrical Engineers, 9th Annual Machine Tool Conference, Hotel Schroeder, Milwaukee, Wis. Nov. 4-6

American Institute of Electrical Engineers and Instrument Society of America, 10th Annual Conference on Electronic Techniques in Medicine and Biology, Harvard University, Cambridge, Mass. Nov. 6-8

Institute of Radio Engineers, 3rd Instrumentation Conference and Exhibit, Theme: Instrumentation for Data Handling, Biltmore Hotel, Atlanta, Ga. Nov. 11-13

Institute of Radio Engineers and American Institute of Electrical Engineers, Conference on Magnetism and Magnetic Materials, Sheraton-Park Hotel, Washington, D. C. Nov. 18-21



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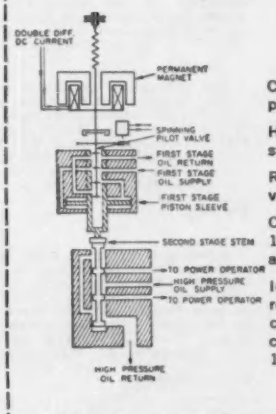

SPECIFICATIONS

Capacities—Up to 600 gpm at 2000 psi drop

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Repeatability—Better than 0.1% full valve stroke

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Here A. E. Sibley (right), Data Systems and Automation section head, discusses new methods of applying digital conversion equipment to a high speed plotting problem with C. M. Wimberley (center), Programming and Mathematical Analysis group leader, and E. K. Fisher, Manager of the Data Services and Mathematics Department. In rear: Electronics Specialist F. A. Alvina operates a recently developed high speed data conversion system producing 704 computer tape directly from originally recorded telemetering tape.

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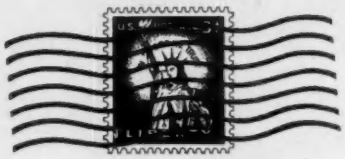

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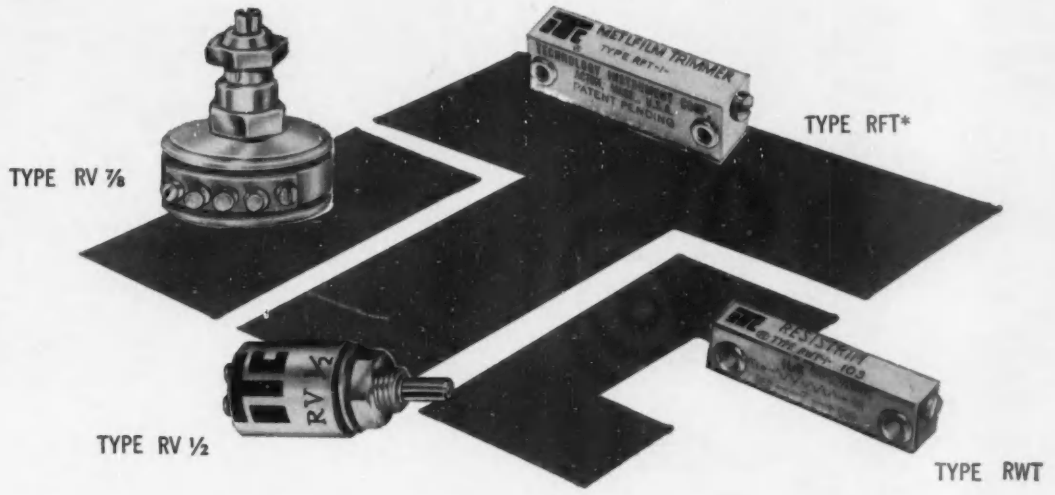

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THE KING and the THREE ROYAL COINERS

There was once a great king who thought to celebrate his fiftieth year by having a new coin struck in his own likeness. He called together his three royal coiners and asked them what they proposed.

The first coiner suggested that the king be portrayed as the great monarch he was—with majestic robes, bejeweled crown, and mighty scepter. The second coiner urged that the king be represented as a humble monarch, as indeed all knew him to be —with royal robes but without crown and scepter. The third coiner thought that the king should be portrayed as both monarch and husband—he therefore proposed that the queen be included on the coin.

After the third coiner had spoken, all three began to quarrel as to which of the proposals was most appropriate to the occasion. The king listened awhile and then ordered them to desist, cease, and be quiet. "This matter is easily resolved," he said in a commanding voice. "We shall assume that all three are fitting and proper to the occasion. So you will, therefore, strike a coin with a single likeness of myself wearing a crown and not wearing a crown, holding a scepter and not holding a scepter, with the queen and not with the queen. You have till noon tomorrow to present me with the required coin."

The three coiners left the palace very much saddened by the task the king had set for them. As they made their way to the royal mint, they discussed how they might render the coin to meet the king's demands. " 'Tis of no avail," said the first coiner. "There is no answer. The king but toys with us." "There must be an answer," squeaked the second coiner, ". . . I'm too young to . . . to . . .!" —he couldn't bear to say it. The third coiner just groaned. And so they continued on their way as silent as tombstones.

By and by they met a jolly old woman who inquired about their long faces and heaviness of spirit. They told her in mournful tones of the command the king had given them. She laughed till their ears rang and said in a creaky voice . . .

"What ne'er is possible in each apart,
May by blending solutions start."

She then reached into her black purse and drew out a shiny penny. In a low voice she began to unfold the simple principle that would enable them to meet the king's demands . . . for a crown and no crown, a scepter and no scepter, a queen and no queen.

When the old woman had concluded, all agreed that what she had shown them was indeed the answer they had been seeking. They paid the old woman well for her help and went straightway to work on the coin.

At the appointed hour, they presented the king with a most unusual coin . . . on one side of the coin the king was portrayed in all his majestic robes, and on the other side there appeared a crown, a scepter, and the queen. When the king saw the coin, he mumbled and grumbled and spoke right out . . . "Do you mock me, you knaves! This does not fulfill the conditions I set for you."

"Ah!" said the first coiner, "begging the king's pardon, but it does . . . allow me to demonstrate." He then took the coin, placed it on edge, and flicked it with his finger so that it spun round and round. Lo and behold, as the king watched the coin he saw the likeness of himself wearing a crown and not wearing a crown, holding a scepter and not holding a scepter, with the queen and not with the queen. The king so marvelled at the resourcefulness of his coiners that he thought to make better use of their talents. He made them tax collectors!

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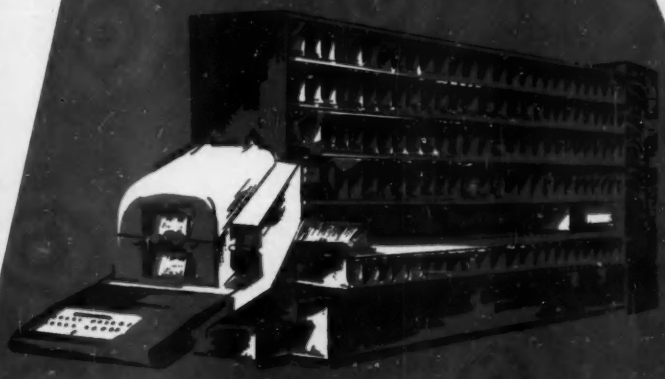

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